

A faint, light-colored watermark of classical architectural elements, specifically four columns supporting a pediment, is visible in the background.

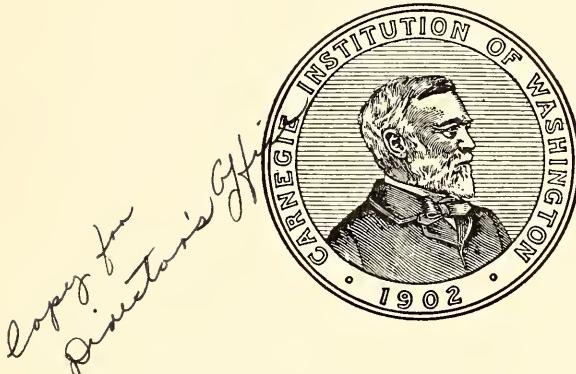
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CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 40

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With Administrative Reports through December 12, 1941



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WASHINGTON, D. C.

1941

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HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

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Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936

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THEODORE DUNHAM, JR.	GUSTAF STRÖMBERG
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EDWIN HUBBLE	RALPH E. WILSON
MILTON L. HUMASON	

TERRESTRIAL SCIENCES

GEOPHYSICAL LABORATORY

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R. W. GORANSON	E. S. SHEPHERD
J. W. GREIG	GEORGE TUNELL
EARL INGERSON	W. D. URRY
F. C. KRACEK	F. E. WRIGHT
O. H. LOEFFLER	E. G. ZIES
H. E. MERWIN	

DEPARTMENT OF TERRESTRIAL MAGNETISM

Organized in 1904; L. A. Bauer, Director 1904-1929

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BIOLOGICAL SCIENCES

DIVISION OF PLANT BIOLOGY

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

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CARL G. HARTMAN (resigned)	

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Organized in 1907, opened in 1908; F. G. Benedict, Director 1907-1937

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V. COROPATCHINSKY	

HISTORICAL RESEARCH

DIVISION OF HISTORICAL RESEARCH

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

A. V. KIDDER, *Chairman*

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NEWTON B. DRURY, Study of Primitive Areas

FRANK A. PERRET, Geophysics
JACK SCHULTZ, Biology
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DEVEREUX JOSEPHS, *Investment Officer*
PARKER MONROE, *Investment Officer*

ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication.

ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership

ARTICLES OF INCORPORATION

to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore

CARNEGIE INSTITUTION OF WASHINGTON

set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912,
December 10, 1937, December 15, 1939, and December 13, 1940

ARTICLE I

THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III

OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.
3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.
4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.
4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Execu-

tive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

ARTICLE V

COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall

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report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII

AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE FORTY-THIRD MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 12, 1941. It was called to order at 10:00 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, Lindsay Bradford, Frederic A. Delano, W. Cameron Forbes, Herbert Hoover, Walter A. Jessup, Frank B. Jewett, Alfred L. Loomis, Henry S. Morgan, Seeley G. Mudd, Elihu Root, Jr., Henry R. Shepley, Richard P. Strong, Charles P. Taft, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Dr. Vannevar Bush, was also in attendance.

The minutes of the forty-second meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1942 were authorized:

Pension Fund	\$ 60,000
Administration	117,520
Publications (including Office of Publications and Public Relations)	52,120
Departmental Research Operations	1,002,885
Research Projects of Limited Tenure.....	60,000

	\$1,292,525

Upon motion of Mr. Hoover, it was

Resolved, That the Board of Trustees of the Carnegie Institution of Washington desire to record their approval of the extent and character of service which the Institution is called upon to render the Government of the United States in connection with the national defense program. The Trustees also approve the action of the President of the Institution in accepting appointment by the President of the United States as Director of the Office of Scientific Research and Development. The Trustees recognize that the needs of the Government and the services which such needs require tend directly to broaden the field and extend the boundaries of knowledge and that the work called for and the resources made available, besides being of national service, are expanding the Institution's scope of usefulness in its own normal sphere. The Trustees desire the Institution to meet all further requests from the United States Government as fully and thoroughly as its facilities and resources will permit.

The Chairman reported the resignation of Mr. Bliss, on account of illness, as a member of the Executive Committee, whereupon Mr. Shepley was elected to fill

CARNEGIE INSTITUTION OF WASHINGTON

the term of Mr. Bliss' election as a member of this Committee. Mr. Gifford and Mr. Walcott were re-elected as members of the Executive Committee for a succeeding term of three years ending in 1944.

The Chairman reported that during the past year vacancies in the Finance Committee created by the resignations of Mr. Loomis and Mr. Morgan had been filled by the Executive Committee, in accordance with specifications of the By-Laws, by temporary appointment of Mr. Bradford and Dr. Jewett, who were thereupon elected by the Trustees as members of the Finance Committee for the ensuing period of three years.

Upon recommendation of the Finance Committee, the following resolutions were authorized:

Resolved, That the Reserve Fund, authorized by action of the Board of Trustees at its meeting of February 18, 1911, to give effect to the stipulation attached to the gift of January 19, 1911, by Mr. Carnegie, be designated hereafter as the Capital Reserve Fund of the Institution.

Resolved, That the Insurance Fund, authorized at the annual meeting of the Board of Trustees on December 15, 1911, and the Special Emergency Reserve Fund, established by the Board of Trustees at its meeting of December 10, 1926, be merged in one fund to be known as the General Reserve Fund and that the available balances to the credit of these two funds as of December 31, 1941, be transferred to the credit of the General Reserve Fund.

The meeting adjourned at 12:15 p.m.

REPORT OF THE EXECUTIVE COMMITTEE FOR THE YEAR ENDING OCTOBER 31, 1941

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1941.

During this year the Executive Committee held six meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A full statement of the work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. The Executive Committee is particularly gratified with the scope and extent of the Institution's contribution toward national defense, which includes administrative services by the President and technical services by many staff members in the interests of defense research. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1942, and budget recommendations are based upon the judgment of these Committees with respect to financial policy in a time of national emergency.

The Board of Trustees, at its meeting of December 13, 1940, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1941. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1941, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1941, showing funds available for expenditure and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

No vacancies exist in the membership of the Board of Trustees, but the tenure of office of Messrs. Gifford and Walcott as members of the Executive Committee expires at the annual meeting on December 12. For consideration at the same time is a vacancy in the membership of the Executive Committee caused by the resignation of Mr. Bliss, which has been regretfully accepted on account of his ill health. The resig-

nation of Mr. Loomis as a member of the Finance Committee was accepted by the Executive Committee at its meeting in January 1941, and Mr. Bradford was appointed at that time to serve as a member of the Finance Committee, in place of Mr. Loomis, until the coming annual meeting of the Board. Similarly the resignation of Mr. Morgan as a member of the Finance Committee was accepted by the Executive Committee at its meeting of November 7, 1941, and Dr. Jewett was temporarily appointed to take his place.

W. CAMERON FORBES, *Chairman*
VANNEVAR BUSH
FREDERIC A. DELANO
WALTER S. GIFFORD
WALTER A. JESSUP
FREDERIC C. WALCOTT
LEWIS H. WEED

November 7, 1941

FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1941

	Balances unallotted Oct. 31, 1940	Trustees' appropriation Dec. 13, 1940	Revertments and transfers Nov. 1, 1940 to Oct. 31, 1941	Total available 1941	Executive Committee allocations 1941	Transfers by Executive Committee	Unallotted balances Oct. 31, 1941
Departmental Research Operations:							
Embryology.....	\$82,372	\$1,100.00	\$82,372.00	\$82,372.00			
Genetics.....	126,270	\$1,.....	130,370.00	130,370.00			
Nutrition Laboratory.....	18,240	.....	18,240.00	18,240.00			
Geophysical Laboratory.....	156,682	3,400.00	160,082.00	160,082.00			
Historical Research.....	129,453	.....	129,453.00	129,453.00			
Mount Wilson Observatory.....	210,230	.....	210,230.00	210,230.00			
Plant Biology.....	74,695	.....	74,695.00	74,695.00			
Terrestrial Magnetism.....	213,525	.....	213,525.00	213,525.00			
Research Projects of Limited Tenure.....	80,000	6,970.83	88,780.87	86,625.00			\$2,155.07
Publications.....	67,580	10,328.52	140,188.43	65,319.43			74,869.00
Administration.....	116,560	5,977.75	122,537.75	122,537.75			
Pension Fund.....	60,000	.....	60,000.00	60,000.00			
General Contingent Fund.....	82,526.86	42,209.65	124,736.51	13,750.00	\$17,977.75		93,008.76
Carnegie Corporation Emergency Fund	82,800.00	166,500.00	249,300.00	144,675.00			104,625.00
	\$229,416.01	\$1,335,607	\$239,486.75	\$1,804,509.76	\$1,511,874.18	\$17,977.75	\$274,657.83

AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1941

RECEIPTS	DISBURSEMENTS
<i>Securities Sold or Redeemed</i>	\$76,944,317.56
<i>Interest from Securities and Bank Balances</i>	48,279,479.17
<i>Sales of Publications</i>	350,335.62
<i>Colburn Estate (Request)</i>	52,015.74
<i>Harriman Fund (Sale of Land)</i>	4,043.70
<i>Teeple Estate (Request)</i>	5,160.62
<i>Carnegie Corporation of New York (Endowment Increase and for Specific Purposes)</i>	8,175,381.24
<i>From Other Organizations and Individuals for Specified Purposes</i>	408,482.86
<i>Pension Fund (Refunds)</i>	90,152.93
<i>Insurance Fund (Refunds)</i>	13,076.02
<i>Administration Building Addition Account, Rentals and Refunds</i>	18,021.09
<i>Miscellaneous Refunds and Receipts</i>	697,373.67
	<i>October 31, 1941, Cash in Banks</i>
	\$135,037,840.22
	\$86,033,016.27
	1,201,443.00
	140,532.24
	38.45
	63,819.41
	261,908.05
	32,808.64
	309,915.69
	416,206.07
	68,570.96
	40,825.37
	<i>Departmental Research Operations:</i>
	Departments of Research, Buildings and Equipment
	30,230,806.00
	Departmental Operations.....
	5,343,100.87
	<i>Research Projects of Limited Tenure</i>
	<i>Publication:</i>
	2,782,139.14
	<i>Administration:</i>
	2,446,078.49
	National Research Council.....
	150,000.00
	Miscellaneous.....
	9,008.82
	\$134,060,535.80
	977,304.42
	\$135,037,840.22

* Includes Equipment \$7,206.41, Repairs and Alterations to Old Building \$18,599.29.

REAL ESTATE AND EQUIPMENT, ORIGINAL COST

Administration (October 31, 1941)

Washington, D. C.

Building, site, and equipment.....	\$847,333.89
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Division of Plant Biology (September 30, 1941)

Stanford University, California (Headquarters)

Buildings and grounds.....	\$77,467.56
Laboratory.....	43,894.87
Library.....	25,483.24
Operating equipment.....	16,954.44

Department of Embryology (September 30, 1941)

Wolfe and Madison Streets, Baltimore, Maryland

Library.....	\$3,909.27
Laboratory.....	17,275.81
Administration.....	7,943.32

Department of Genetics (September 30, 1941)

Cold Spring Harbor, Long Island, New York

Buildings, grounds, field.....	\$288,877.35
Operating equipment.....	32,699.50
Laboratory apparatus.....	33,287.29
Library.....	50,467.88
Archives.....	45,488.90

Geophysical Laboratory (September 30, 1941)

2801 Upton Street N.W., Washington, D. C.

Building, library, operating appliances.....	\$277,544.90
Laboratory apparatus.....	171,072.96
Shop equipment.....	20,935.00

Division of Historical Research (September 30, 1941)

Administration Building, Washington, D. C.

Operating equipment.....	\$31,524.71
Library.....	10,287.18

Nutrition Laboratory (September 30, 1941)

29 Vila Street, Boston, Massachusetts

Building, office, shop, and library.....	\$134,434.30
Laboratory apparatus.....	36,472.03

Mount Wilson Observatory (September 30, 1941)

Pasadena, California

Buildings and grounds.....	\$222,458.33
Shop equipment.....	47,222.94
Instruments.....	683,068.43
Furniture and operating appliances.....	145,773.68
Hooker 100-inch reflector.....	633,980.51

Department of Terrestrial Magnetism (September 30, 1941)

5241 Broad Branch Road N.W., Washington, D. C.

Building, site, and office.....	\$242,755.05
Survey equipment.....	93,046.38
Instruments, laboratory, and shop equipment.....	449,845.95

\$4,691,505.67

REPORT OF AUDITORS

*To the Board of Trustees
Carnegie Institution of Washington
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1941.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were verified by certificates received from depositories and custodians. As in past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution, and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost, amortized cost, or value at date acquired, this being the established custom of the Institution. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, all premiums on all obligations purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the date on which an obligation is first callable or payable at par. The amortization of the premiums applicable to the year ended October 31, 1941 amounted to \$14,712.56 and has been deducted from the cost of such obligations.

Real estate and equipment are stated at original cost and books on hand for sale at their sales prices. No provision has been made for depreciation of property owned by the Institution.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying balance sheet, statement of receipts and disbursements, and detailed schedule of securities properly present the financial position of Carnegie Institution of Washington at October 31, 1941 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY
Accountants and Auditors

*New York, N. Y.
November 28, 1941*

BALANCE SHEET OCTOBER 31, 1941

ASSETS	LIABILITIES
<i>Investments</i>	
Securities.....	\$31,737,043.07
Cash:	
Awaiting investment	554,040.60
Reserved for current needs.....	113,515.91
	\$32,404,599.58
<i>Property Account</i>	
Real Estate and Equipment at original cost:	
Office of Administration.....	\$847,333.89
Departments of Research.....	3,844,171.78
	4,691,505.67
<i>General Fund</i>	
Cash:	
Income account.....	\$309,747.91
Petty cash and stamps.....	50.00
	\$310,247.91
Income uncollected for the calendar year 1941.....	266,701.74
Books on hand at sale price.....	211,484.25
Outstanding accounts on sales of publications.....	342.74
Paper and supplies in stock for future publications.....	1,850.21
	790,626.85
	\$37,886,732.10
<i>Endowment and Other Funds</i>	
<i>Capital Funds</i>	
Endowment Fund	\$29,595,014.78
Colburn Fund.....	110,485.48
Reserve Fund.....	3,132,156.59
Harriman Fund (\$179,638.05 included in Property Fund below)	311,482.03
Teepie Fund.....	5,104.45
<i>Special Funds</i>	
Insurance Fund.....	\$33,154,243.33
Penion Fund.....	705,380.97
Special Emergency Reserve Fund	307,689.44
Current Funds Invested.....	368,504.66
	160,000.00
	\$34,695,818.40
<i>Property Fund</i>	
Less Loss from redemption and sale of securities (awaiting yearly ap- portionment)	\$32,404,599.58
Income Invested.....	2,291,218.82
Harriman Property (Gift)	\$4,511,877.62
	179,628.05
<i>General Fund</i>	
Current Obligations:	
Departmental Research Operations.....	\$243,825.02
Research Projects of Limit- ed Tenure.....	49,975.30
Publications.....	110,381.50
Administration.....	33,385.46
General Contingent Fund ..	103,308.71
Carnegie Corporation, Emergency Fund.....	125,016.36
Unappropriated Fund.....	\$665,992.35
	70,957.30
	\$736,949.65
Less Current Funds, In- vested (see above).....	\$576,949.65
	160,000.00
Value of Publications and Invoices.....	211,826.99
Publication Paper and Sup- plies in Stock	1,850.21
	790,626.85
	\$37,886,732.10

RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED OCTOBER 31, 1941

RECEIPTS	DISBURSEMENTS	
Securities Redeemed or Sold	\$7,179,530.22	
Interest and Dividends from Securities.....	1,398,562.78	
Sales of Publications.....	4,044.09	
Refunds and Other Credits.....	206,746.88	
From Other Organizations and Individuals for Specific Purposes:		
Carnegie Corporation of New York	151,000.00	
National Research Council	3,120.00	
California Institute of Technology	4,999.92	
Rockefeller Foundation.....	1,500.00	
Contributions.....	800.00	
Pension Fund (Refunds).....	3,878.65	
Insurance Fund (Refunds).....	120.51	
	\$8,954,303.05	
Cash in Banks, October 31, 1941:		
Uninvested principal:		
Awaiting investment.....	\$554,040.60	
Reserved for current needs	113,515.91	
Income Account.....	1,395,888.33	
	\$10,350,191.38	
	\$9,372,886.96	
	Cash in Banks, October 31, 1941:	
	Uninvested principal:	
	Awaiting investment.....	\$554,040.60
	Reserved for current needs	113,515.91
	Income Account.....	309,747.91
		\$667,556.51
		977,304.42
		\$10,350,191.38

* Includes specific terminating projects administered through departments.

SCHEDULE OF SECURITIES

Aggregate— par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired
UNITED STATES GOVERNMENT BONDS			
\$160,000	U. S. Guar. Commodity Credit Corp. Notes, 1 1/8s	1945	\$160,000.00
300,000	U. S. Guar. Federal Farm Mtg. Corp., 3s.....	1949-44	315,351.55*
300,000	U. S. Guar. Home Owners Loan Corp., 1 1/2s.....	1947-45	303,215.63*
120,000	U. S. Guar. Reconstruction Finance Corp. Notes, 1s.....	1944	120,000.00
850,000	U. S. of America Treasury, 2s.....	1950-48	856,993.30*
1,489,000	U. S. of America Treasury, 2 1/2s.....	1954-52	1,497,617.15*
300,000	U. S. of America Treasury, 2 1/2s.....	1958-56	300,000.00
250,000	U. S. of America Treasury, 2 1/2s.....	1972-67	250,000.00
50,000	U. S. of America Savings Defense "G," 2 1/2s.....	1953	50,000.00
\$3,819,000	Total U. S. Government.....	.....	\$3,853,177.63
FOREIGN BONDS			
\$55,000	Dominion of Canada, 5s.....	1952	\$60,450.00
182,000	Canadian National Ry. Co., 4 1/2s, Guar.....	1951	182,740.00*
100,000	Canadian National Ry. Co., 4 1/2s, Guar.....	1957	112,000.00
100,000	Canadian National Ry. Co., 5s, Guar.....	1969	98,500.00
91,000	Canadian Pacific Ry. Co., Coll. Trust 5s.....	1954	90,835.11
100,000	Province of Alberta, Deb. 4 1/2s.....	1958	93,750.00
100,000	Province of Alberta, Deb. 5s.....	1950	101,150.00
150,000	Province of Manitoba, Deb. 4 1/2s.....	1958	142,886.77
100,000	Province of Nova Scotia, Deb. 4 1/2s.....	1952	100,312.50
40,000	Province of Ontario, Deb. 6s.....	1943	43,137.50
250,000	Shawinigan Water and Power Co., 1st Mtg. & Coll. Trust S. F. 4 1/2s.....	1967	238,510.42
100,000	City of Toronto, Cons. Loan Deb. Ss.....	1949	96,164.59
\$1,368,000	Total Foreign.....	.....	\$1,360,436.89
PUBLIC UTILITY BONDS			
\$100,000	Alabama Power Co., 1st & Ref. Mtg. 4 1/2s.....	1967	\$87,265.00
231,000	Alabama Power Co., 1st & Ref. Mtg. 5s.....	1968	219,516.25
109,000	American Gas & Electric Co., S. F. Deb. 2 3/4s.....	1950	111,180.00*
300,000	Arkansas Power & Light Co., 1st & Ref. Mtg. 5s.....	1956	292,312.50
75,000	Blackstone Valley Gas & Electric Co., Mtg. & Coll. Trust 4s.....	1965	76,875.00
380,000	Columbia Gas & Electric Corp., Deb. 5s.....	1961	379,762.50
249,000	Columbus & Southern Ohio Electric Co., 1st Mtg. 3 1/4s.....	1970	268,099.55*
23,900	Commonwealth Edison Co., Conv. Deb. 3 1/2s.....	1958	23,910.75
83,000	Commonwealth Edison Co., 1st Mtg. 3 1/2s.....	1968	85,712.87
50,000	Consolidated Edison Co. of New York, Deb. 3 1/2s.....	1948	50,875.00
40,000	Consolidated Edison Co. of New York, Deb. 3 1/2s.....	1958	40,730.00
100,000	Detroit Edison Co., Gen. & Ref. Mtg. 4s.....	1965	103,500.00
200,000	Gulf States Utilities Co., 1st Mtg. & Ref. 3 1/2s.....	1969	213,500.00
25,000	Houston Lighting & Power Co., 1st Mtg. 3 1/2s.....	1966	25,750.00
200,000	Illinois Power & Light Corp., 1st & Ref. Mtg. 5s.....	1956	196,750.00
150,000	Louisiana Power & Light Co., 1st Mtg. 5s.....	1957	154,900.00
100,000	Metropolitan Edison Co., 1st Mtg. 4 1/2s.....	1968	109,470.00
100,000	Minnesota Power & Light Co., 1st & Ref. Mtg. 4 1/2s.....	1978	92,156.25
50,000	Monongahela West Penn Public Service Co., 1st Mtg. 4 1/2s.....	1960	52,000.00
99,000	Montana Power Co., 1st & Ref. Mtg. 3 1/2s.....	1966	99,990.00
100,000	New Orleans Public Service Co., 1st & Ref. Mtg. 5s.....	1955	99,200.00
65,000	New York & Westchester Lighting Co., Deb. 5s.....	1954	67,052.50
47,000	North American Co., Deb. 3 1/2s.....	1949	47,822.50
50,000	Northern States Power Co., 1st & Ref. Mtg. 3 1/2s.....	1967	47,500.00
100,000	Ohio Edison Co., 1st Mtg. 4s.....	1967	100,266.25
100,000	Ohio Power Co., 1st Mtg. 3 1/2s.....	1968	101,500.00
100,000	Ohio Public Service Co., 1st Mtg. 4s.....	1962	102,625.00
200,000	Oklahoma Gas & Electric Co., 1st Mtg. 3 1/2s.....	1966	205,000.00
97,000	Oklahoma Natural Gas Co., 1st Mtg. 3 1/2s.....	1955	104,507.80
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 3 1/2s.....	1961	102,500.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 4s.....	1964	104,000.00
200,000	Pennsylvania Electric Co., 1st & Ref. Mtg. 5s.....	1962	203,882.50
141,000	Public Service Co. of Northern Illinois, 1st Mtg. 3 1/2s.....	1968	145,230.00
60,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 4 1/2s.....	1950	56,550.00
50,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 5 1/2s.....	1949	31,900.00
300,000	Southern California Edison Co., Ltd. 1st & Ref. Mtg. 3s.....	1965	314,577.60*
150,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3 1/2s.....	1956	154,429.32*
300,000	Texas Electric Service Co., 1st Mtg. 5s.....	1960	292,700.00
195,500	Texas Power & Light Co., 1st & Ref. Mtg. 5s.....	1956	200,528.02
120,000	Toledo Edison Co., 1st Mtg. 3 1/2s.....	1968	121,800.00
263,000	Virginia Electric & Power Co., 1st & Ref. Mtg. 3 1/2s.....	1968	272,205.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3 1/2s.....	1968	232,875.00
\$5,728,400	Total Public Utility.....	.....	\$5,792,907.16

* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

SCHEDULE OF SECURITIES—Continued

Aggregate— par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired
COMMUNICATION BONDS			
\$284,000	American Telephone & Telegraph Co., Conv. Deb. 3s.....	1956	\$315,266.88*
51,000	American Telephone & Telegraph Co., Deb. 3½s.....	1961	51,510.00
314,000	American Telephone & Telegraph Co., Deb. 3 ¼s.....	1966	326,706.75
25,000	Mountain States Telephone & Telegraph Co., Deb. 3 ½s.....	1968	25,500.00
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s.....	1952	51,748.00
75,000	Southern Bell Telephone & Telegraph Co., Deb. 3 ¾s.....	1962	72,375.00
\$801,000	Total Communications.....	.....	\$843,106.63
RAILROAD EQUIPMENT TRUSTS			
\$90,000	Erie R. R. Co., 4 ½s, Guar.....	1942-43	\$86,467.90
120,000	Illinois Central R. R. Co., 4 ½s.....	1942-44	115,184.84
50,000	Missouri Pacific R. R. Co., 4 ½s.....	1942	47,864.42
\$260,000	Total Railroad Equipment Trusts.....	.....	\$249,517.16
RAILROAD BONDS			
\$200,000	Atchison, Topeka & Santa Fe Ry. Co., 1st & Ref. Mtg. 4 ½s.....	1962	\$199,500.00
50,000	Central Pacific Ry. Co., 1st Ref. Mtg. 4s, Guar.....	1949	48,250.00
100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4 ½s.....	1992	99,464.29
75,000	Chicago & Western Indiana R. R. Co., Cons. 4s.....	1952	70,357.66
50,000	Great Northern Ry. Co., 1st & Ref. Mtg. 4 ½s, Std.....	1961	50,113.59
100,000	Great Northern Ry. Co., Gen. Mtg. 5s.....	1973	104,385.84
150,000	Louisville & Nashville R. R. Co., 1st & Ref. Mtg. 4 ½s.....	2003	149,475.00
50,000	New York, Pennsylvania & Ohio R. R. Co., Prior Lien 4 ½s.....	1950	52,500.00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s.....	1946	48,405.15
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4 ½s.....	1965	75,918.75
100,000	Pennsylvania R. R. Co., Cons. Mtg. 4 ½s.....	1960	104,662.50
50,000	Pittsburgh, Cincinnati, Chicago & St. Louis R. R. Co., Gen. Mtg. 5s, Guar.....	1975	51,898.98
100,000	Southern Ry. Co., 1st Cons. Mtg. 5s.....	1994	103,580.34
70,000	Terminal R. R. Assn. of St. Louis, S. F. Gen. Ref. Mtg. 4s.....	1953	63,603.92
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3 ¾s, Guar.....	1960	99,000.00
2,084,000	Union R. R. Co., Deb. 6s, Guar.....	1946	2,084,000.00
100,000	Virginia Ry. Co., 1st Lien & Ref. Mtg. 3 ¾s.....	1966	102,250.00
100,000	West Shore R. R. Co., 1st Mtg. 4s, Guar.....	2361	78,149.00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 ½s.....	1977	42,677.19
\$3,654,000	Total Railroad.....	.....	\$3,628,183.21
INDUSTRIAL AND MISCELLANEOUS BONDS			
\$21,000	Allis-Chalmers Mfg. Co., Conv. S. F. Deb. 4s.....	1952	\$21,666.54
50,000	Atlantic Refining Co., Deb. 3s.....	1953	51,187.50
150,000	Bethlehem Steel Corp., Conv. S. F. Deb. 3 ½s.....	1952	148,750.00
208,000	Loew's Incorporated, S. F. Deb. 3 ½s.....	1946	213,464.03
5,000	Phelps Dodge Corp., Conv. Deb. 3 ½s.....	1952	5,000.00
200,000	Phillips Petroleum Co., Conv. Deb. 1 ¾s.....	1951	200,000.00
140,000	Railway Express Agency, Serial Notes 1 ½s-2 ½s.....	1942-48	140,000.00
100,000	Republic Steel Corp., Gen. Mtg. 4 ½s.....	1956	104,236.42*
98,000	Republic Steel Corp., Gen. Mtg. 4 ½s.....	1961	101,474,80*
95,000	Scovill Manufacturing Co., Deb. 3 ½s.....	1950	96,688.89*
400,000	Shell Union Oil Corp., Deb. 2 ½s.....	1954	384,176.25
75,000	Socony Vacuum Oil Co., Deb. 3s.....	1964	78,000.00
150,000	Standard Oil Co. of California, Deb. 2 ½s.....	1966	153,750.00*
100,000	Standard Oil Co. of New Jersey, Deb. 2 ½s.....	1953	99,000.00
1,925,000	Tennessee Coal, Iron & R. R. Co., Gen. Mtg. 5s (Payment Guar. by U. S. Steel Corp.).....	1951	1,925,000.00
197,000	West Virginia Pulp & Paper Co., 1st Mtg. 3s.....	1954	195,030.00
\$3,914,000	Total Industrial and Miscellaneous.....	.....	\$3,917,424.43
MORTGAGES			
\$96,710.44	Lawyers Mtg. Co., Guaranteed 1st Mtg. Ctfs., Series 18397T 4%.....	1944	\$96,710.44
100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Ctfs., 4 ½%, No. 29940T.....	1940	100,000.00
80,000	Lawyers Title & Guar. Co., 5 ½% Mtg., Par Ctfs. No. D 424421381.....	1935	80,000.00
90,000	N. Y. Title & Mtg. Co., Guaranteed 1st Mtg. Ctfs., 5 ½%, No. N97.....	1938	90,000.00
95,750	N. Y. Title & Mtg. Co., Guaranteed 1st Mtg. Ctfs., 4 ½%, No. N86.....	1940	95,750.00
90,000	Participating Ctf. in Consol. Bond & Mtg., SE. corner Madison Ave. and 40th St., Manhattan, 4%.....	1944	90,000.00
\$552,460.44	Total Mortgages.....	.....	\$552,460.44
\$20,096,860.44	BONDS AND MORTGAGES—Funds Invested.....	.....	\$20,197,213.55

* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

SCHEDULE OF SECURITIES—Continued

Number of shares	Description	Cost, amortized cost, or value at date acquired
PREFERRED STOCKS		
100	American Brake Shoe and Foundry Co., 5 1/4% Cum. Pref.	\$12,653.50
1,310	American Cyanamid Co., 5% Cum. Pref.	14,771.25
1,500	Appalachian Electric Power Co., 4 1/4% Cum. Pref.	159,000.00
1,500	Bethlehem Steel Corp., 7% Cum. Pref.	183,637.50
500	J. I. Case Threshing Machine Co., 7% Cum. Pref.	62,225.00
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref.	68,112.25
1,000	Deere & Co., 7% Cum. Pref.	28,812.50
1,125	E. I. Du Pont de Nemours & Co., \$4.50 Cum. Pref.	116,125.00
1,500	General Motors Corp., \$5.00 Cum. Pref.	187,937.50
225	Grant Co. (W. T.), 5% Cum. Pref.	7,642.76
530	Johns-Manville Corp., 7% Cum. Pref.	67,294.52
1,000	New York State Electric & Gas Corp., 5.10% Cum. Pref.	103,250.00
1,000	Northern States Power Co., \$5.00 Cum. Pref.	103,000.00
1,100	Ohio Oil Co., 6% Cum. Pref.	120,376.14
550	Ohio Power Co., 4 1/2% Cum. Pref.	59,925.00
550	Oklahoma Natural Gas Co., \$5.50 Cum. Conv. Prior Pref.	62,142.51
600	Public Service Co. of Oklahoma, 5% Cum. Pref.	60,900.00
1,174	Sherwin-Williams Co., 5% Cum. Pref.	129,394.63
1,000	Southwestern Gas & Electric Co., 5% Cum. Pref.	110,350.00
1,000	Standard Oil Co. of Ohio, 5% Cum. Pref.	109,385.47
3,100	United States Steel Corp., 7% Cum. Pref.	443,407.57
20,964	Total Preferred Stocks.....	\$2,210,343.10
COMMON STOCKS		
1,800	Air Reduction Co.	\$107,905.16
2,000	American Brake Shoe and Foundry Co.	87,580.95
1,500	American Can Co.	136,846.00
5,600	American Cyanamid Co. "B"	162,591.00
4,000	American Radiator & Standard Sanitary Corp.	73,114.91
1,400	American Tobacco Co.	106,406.50
200	American Tobacco Co. "B"	16,342.00
1,600	Bethlehem Steel Corp.	125,270.00
2,600	Caterpillar Tractor Co.	175,811.00
1,900	Chase National Bank of New York	61,775.00
2,400	Chrysler Corp.	226,638.50
1,500	Commercial Credit Co.	72,258.75
1,900	Commercial Investment Trust Corp.	112,346.24
150	Commercial National Bank and Trust Co. of New York	26,880.00
2,700	Continental Can Co.	118,124.50
2,408	Continental Insurance Co.	87,913.30
3,500	Continental Oil Co. of Delaware	149,622.50
2,900	Deere & Co.	57,720.36
1,760	Dow Chemical Co.	211,240.00
2,300	E. I. Du Pont de Nemours & Co.	363,723.00
1,600	Eastman Kodak Co. of New Jersey	252,428.75
35	Fifth National Bank of New York	60,925.00
10,600	General Electric Co.	417,371.50
2,800	General Foods Corp.	114,615.00
7,600	General Motors Corp.	390,669.00
3,600	Grant Co. (W. T.)	119,318.24
440	Guaranty Trust Co. of New York	115,954.00
5,300	Gulf Oil Corp.	196,858.50
900	Hartford Fire Insurance Co.	69,384.68
3,800	Humble Oil & Refining Co.	219,969.50
1,000	Ingersoll-Rand Co.	107,083.00
920	Inland Steel Co.	90,662.50
1,200	Insurance Co. of North America	79,238.15
822,45	International Business Machines Corp.	116,998.00
1,000	International Harvester Co.	82,476.25
800	Johns-Manville Corp.	76,687.15
3,000	Kennecott Copper Corp.	129,293.38
4,500	Kresge Co. (S. S.)	104,500.00
1,100	Liggett & Myers Tobacco Co. "B"	110,625.00
3,200	Monsanto Chemical Co.	320,906.00
4,100	Montgomery Ward & Co.	220,701.08
5,100	National Lead Co.	108,585.50
2,000	Newberry Co. (J. J.)	94,190.00
2,600	New Jersey Zinc Co.	172,294.50
3,200	Owens-Illinois Glass Co.	197,239.00
2,900	Parke, Davis & Co.	107,042.00
2,500	Penny Co. (J. C.)	229,123.50
3,900	Phelps Dodge Corp.	145,754.79
1,200	Pittsburgh Plate Glass Co.	131,399.75
1,800	Procter & Gamble Co.	100,795.82
900	Pullman Inc.	43,073.18
1,200	St. Joseph Lead Co.	54,506.57
3,100	Sears, Roebuck & Co.	244,900.90

(Continued on following page)

SCHEDULE OF SECURITIES—*Continued*

Number of shares	Description	Cost, amortized cost, or value at date acquired
COMMON STOCKS— <i>Continued</i>		
1,500	Sherwin-Williams Co.	\$147,079.47
8,000	Socony Vacuum Oil Co.	95,645.00
4,000	Standard Oil Co. of California	127,044.00
2,600	Standard Oil Co. of Indiana	75,550.50
1,858	Standard Oil Co. of New Jersey	98,627.38
4,300	Texas Corp.	181,018.76
2,800	Timken Roller Bearing Co.	136,062.00
120	Travelers Insurance Co.	59,433.11
3,800	Union Carbide & Carbon Corp.	321,683.50
1,500	United Fruit Co.	109,972.00
1,200	United States Gypsum Co.	120,301.00
600	United States Steel Corp.	61,573.34
2,700	Westinghouse Electric & Manufacturing Co.	289,816.50
169,813.45	Total Common Stocks	\$9,329,486.42
190,777.45	COMMON AND PREFERRED STOCKS—Funds Invested	\$11,539,829.52
	AGGREGATE INVESTMENTS (BONDS AND STOCKS)	\$31,737,043.07

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1941

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

The President has the honor to report to the Trustees, in accordance with the provision in the By-Laws of the Institution, on the research activities for the year ending October 31, 1941, on financial and organizational matters, and on the relation of the Institution to the United States Government during this period of emergency.

Events of the past two years have profoundly altered the plans and outlook of every scientific institution in the world, and of the great majority of individual scientists. The Carnegie Institution of Washington is so constituted that it is bound to be deeply involved in that aspect of the present intense national effort which is concerned with the application of the natural sciences to national defense, and it is necessary and fitting that the Institution should respond fully to the call of government in this regard. Inevitably, therefore, many of its long-range programs of research in the field of pure science have now been changed or held in abeyance.

There is not complete unanimity in this country as to how, or when, or to what extent the power of the nation should be exerted to defend our way of life. There is substantial unanimity, however, on the thesis that the power of the nation should be increased as rapidly as possible and to the maximum possible extent. Here the Institution has a very definite duty. Military strength has been definitely demonstrated to depend, in no inconsiderable degree, upon the intelligent application of science to military devices and operations. As a great and unique scientific organization of national extent, with its

central offices close to the seat of government, the Institution has a duty far beyond that of responding passively to the calls of government for the loan of the services of members of its staff. It is called upon to participate actively, in close cooperation with other scientific groups, in bringing to the aid of government the coordinated intense effort of the scientists of this country, supplementing the activities of the armed services, in order that the weapons placed in the hands of the youth of the land may be fully adequate. The scientists of the Institution are discharging this duty to the full extent of their ability and opportunity.

During the past three years, in view of declining income, and with the knowledge that the affairs of all organizations require periodic evaluation, there occurred a retraction in several of the Institution's activities. Matured efforts were brought to an end, or turned over to other organizations, as the retirement of several notable scientists of the staff from active work occasioned alterations of program. This curtailment was substantially completed some time ago. It was to have been followed by an intensification of effort in fields where opportunity seemed greatest, and by new approaches to old problems with more modern instrumentation. The generosity of Carnegie Corporation of New York made a start in this direction possible. The construction of a large cyclotron was begun, to implement an attack on many problems in the borderland between physics and biology. A study was undertaken looking toward a new approach to human

genetics. In many other fields plans were being formulated for new work and for extended collaboration with other scientific groups engaged in research which closely parallels that in our own laboratories. This whole program is not now stopped, but it is decidedly slowed down. Part of this retardation is due to reluctance to request and use materials which are restricted, unless the objective is a part of the defense effort. Much more of it is due to the fact that those who had intended to lead new scientific ventures are now occupied with other things. Finally, in certain highly active fields, young capable scientists are hard to obtain, even for defense research. Few of them are inclined to proceed with long-range pure research, rather than with the immediate matters of defense, and one hardly wishes to urge them to do so.

There is, therefore, little to report this year of new scientific undertakings, or important construction of new facilities. The duration of the pause cannot be foreseen, but the plans will not be lost, and will in fact become more completely matured during the interruption.

In previous reports, during this period of stress, it has been emphasized that the Institution has a duty in addition to that of participation in defense. Fundamental scientific research is almost completely stopped all over the world, except in this hemisphere. The inspiration passed from master to disciple, and the subtle evolution

of great ideas when powerful minds collaborate, or compete, are part and parcel of the rapid progress of modern science. This implies continuity of effort. If the thread is broken it may be long before it can be mended. With science and scientists in other lands completely distracted by immediate requirements, an organization such as ours has a responsibility for preserving some of the more important threads intact. This duty has not been forgotten, although its fulfillment becomes increasingly difficult.

Aside from the difficulties inherent in the emergency, the health of the Institution remains sound. Budgets are thus far balanced without calling seriously on reserves at any point. The portfolio of investments has been strengthened, with a considerable decrease in book value of capital funds as weak issues have been disposed of, and with some further decrease in current income. What may lie ahead in this regard cannot be at all predicted. The health of the Institution depends ultimately upon the health of the country. If the country returns to days of peace in sound condition, then the problems of the Institution can be solved, for it occupies a unique and important place in scientific affairs in this land, and scientific effort, devoted to the extension of man's fundamental knowledge of his environment, will most certainly go on if the world returns to peaceful pursuits.

DEFENSE ACTIVITIES

In accordance with authorization from the Trustees, the services of staff members and the use of laboratory facilities of the Institution have been made available to the government. In some cases staff members have been given leave of absence in order to enter the rolls of governmental organizations; in others, their services have

been made available while they remained on salary with the Institution, working either in our own or in governmental laboratories. At the present time eleven staff members are thus on leave, twenty others are giving full time to defense research in our own laboratories, and over forty more are devoting part time in connection with

various advisory committees, as consultants to the Army and Navy, and in similar capacities. Much of the work in our own laboratories is carried on under contract with governmental agencies, the Institution being reimbursed for its added expenses in carrying out the work, but not for the regular expenses of the laboratory, the overhead, or the salaries of scientists on the staff. This has allowed a greater expansion of the work than would have been possible had the Institution made the entire contribution. The heaviest burden has fallen on the Department of Terrestrial Magnetism, where nearly all the research is now on governmental problems, and the number of men in that laboratory in all categories has been more than doubled in order to carry it on. The Geophysical Laboratory, the Mount Wilson Observatory, and the Nutrition Laboratory also have important efforts under way. The amount of the government funds made available for the added expenses of those programs has now reached nearly two-thirds of the normal budget of the Institution.

This type of work is now being done in scientific laboratories all over the country; it was concentrated at first, of necessity, in some of the larger institutions, but gradually it is reaching out to others. The whole program is being enlarged to meet increased needs, especially in the field of medical research.

In order that the combined effort may be properly integrated, the President of the United States has, by Executive Order, created the Office of Scientific Research and Development as a part of the Office for Emergency Management, and has given this Office the task of coordinating all defense research, and, through its subordinate bodies, of supplementing the research of the Army and Navy in the development of instrumentalities of warfare,

and in medical research connected with defense. The President of the Institution is Director of this Office, and many staff members are members of its organization. Its main offices are located in the Administration Building of the Institution, under an arrangement whereby space, furnished at first to the government at nominal cost, is now made available for government purposes without charge. The Chairman of the National Defense Research Committee, which is a part of the Office, is now President James B. Conant, of Harvard University, and the Chairman of its Committee on Medical Research is Dr. A. Newton Richards, of the University of Pennsylvania. The Office has close relations with all governmental agencies and private organizations concerned with defense research. It has especially close relations with the National Academy of Sciences, which is the advisory body to all governmental agencies on their scientific programs, and of which our fellow Trustee, Dr. Frank B. Jewett, is President; and with the National Research Council, with which many of our staff are associated, the important Medical Division being headed by Dr. Lewis H. Weed, of the Board of Trustees.

Many of the dislocations and stresses produced by the emergency are not pleasant. There is, however, one decidedly pleasant aspect of the matter. Owing to the close connection of the Institution with the defense research effort there is a continual succession of visits to the headquarters of the Institution from the outstanding scientists of the country, from members of our own staff from a distance, and from the many Trustees of the Institution who are concerned with various aspects of the defense problem. When the emergency is over the scientists of the country will be better acquainted with one another, and they will also be better acquainted with the

CARNEGIE INSTITUTION OF WASHINGTON

Institution. This should certainly be of real benefit when our full normal program again occupies our laboratories, and when

our aid and collaboration again become fully extended to those in other institutions whose research is closely allied to our own.

RETIREMENTS AND PERSONNEL

The Bursar of the Institution, Mr. E. A. Varela, after extending his active service for a year at the request of the President, retired on January 1, 1941. With his long experience, sound judgment, and single-minded loyalty, his service has been of great value. He has been making a post-retirement study of accounting methods in the various departments of the Institution, and of the Institution's general financial program.

The Institution's support of a program of experimental ecology over a period of twenty-seven years was brought to a close with the retirement of Dr. F. E. Clements on October 1, 1941. During this period a long series of interesting investigations has tested and elaborated certain ecological principles which had been outlined as early as 1898 in a joint publication by Roscoe Pound and Frederic E. Clements. Dr. Clements has evolved, during almost a half-century of study of the ecology of the western United States, a comprehensive concept of the relations of plant communities to the natural processes of the environment, and this is proving to be of much value in the administration of public lands. In accordance with present plans, he hopes to be able to continue his investigations and bring further results to a point of publication.

Dr. A. F. Blakeslee, Director of the Department of Genetics, retires on Decem-

ber 1, 1941, after a long and distinguished career of scientific accomplishment. He has been, and is, one of the great biologists of this country, with a rare combination of intuitive judgment and experimental skill which have led to striking advances in his subject. Although he is relinquishing his executive work, his personal research efforts will, it is hoped, continue for many years.

Dr. C. G. Hartman has resigned to accept an important post at the University of Illinois, where he will have continued opportunity to carry on his own researches on the physiology of reproduction, in which he is a recognized authority. Dr. Samuel R. M. Reynolds, of the Long Island College of Medicine, has been appointed to fill the vacancy thus created in the staff of the Department of Embryology. Dr. W. M. Manning, of the University of Wisconsin, has been called to augment the staff of investigators at the Division of Plant Biology concerned with studies in photosynthesis.

In the death of Dr. Andrade, of the University of Chicago, the Institution has lost the collaboration of a Research Associate who was an important contributor to studies of linguistic science. He applied new methods of linguistic analysis in studies of early languages of Middle America, in cooperation with the program of the Division of Historical Research.

FINANCES

Action of the Finance Committee during the past year has caused many changes in the Institution's investment list, marked

by sale of railroad bonds and purchases of additional stocks and government bonds. Such changes have had the effect of reduc-

tion of book value, but they have also strengthened the Institution's holdings without serious reduction of income. Our position, therefore, so far as current estimated income is concerned, is nearly the same as it was a year ago when budget recommendations for the current year were prepared. Moreover, the year 1940 closed with another excess of income over estimates, although smaller than in the preceding year. Such a situation cannot be expected to continue under existing conditions, but it is probable that a portion of the excess of income for 1940 may be held available for use in balancing subsequent budgets.

As a result of the termination of certain obligations for grants for research,

and of a reduction in the number of new projects and field programs, a budget is accordingly presented for next year which is balanced by utilizing unappropriated income of the previous years, without expectation that there will be any call on reserves. There remains a sufficient amount in the General Contingent Fund to cover such extra expenses and readjustments as may normally be expected.

One aspect of the situation is not so favorable. Costs of operation are increasing constantly, and the matter of salaries, particularly in the lower brackets, will require attention if we are to maintain effectively such normal activities of the Institution as can still be pursued, and also carry out our emergency obligations.

REVIEW

A review of all the activities of the Institution would make interesting reading, but it will have to wait until the time comes when the full story can be told. It is now impossible to mention fine work being done by many of the staff members of the Institution, since it remains in a confidential category.

The normal research activities of the staff, in view of the interruptions and distractions now present, are not inconsiderable. The full Year Book gives the record, again with an interpretive statement by each Director of a Department or Division. Here a few high lights will be noted, in the hope that this will lead to further perusal.

In spite of preoccupation of most of the staff members of the Department of Terrestrial Magnetism with defense research, the fundamental program of this department still continues significantly. Unless further delays accrue in procuring materials for which priorities are sought, the cyclotron will shortly be completed and

made available for cooperative studies in which the Department of Embryology and the Department of Genetics will have a part. Searchlight studies of the electrical and chemical conditions of the air at great heights are also progressing, as well as coordination of magnetic, solar, and upper-air studies as related particularly to problems of radio transmission.

Dr. Adams reports from Mount Wilson a number of interesting results. To seize upon one of these, he tells of the first definite evidence of the presence of iron in interstellar space, the density being such that there is present roughly one atom in a cubic meter. This is a very low density. The best vacuum man has produced artificially still contains gas many million times as dense. Yet interstellar space is so enormous that the mass of material represented in these gases is large, and the significance of the discovery may be great. Continued study of atomic and molecular spectral lines from this vast area may in time give us not only the composition but

also the distribution and motions of the clouds of cosmic dust and gas that inhabit it, and provide much knowledge of the physical state of its matter. Another item relates to the discovery of the remains of Kepler's Nova of 1604 through the use of red-sensitive plates, and its recognition as the third supernova to appear in the observable region of the galactic system within the last 900 years. Finally, the vexed question of the direction of rotation of the great universes of stars represented by the spiral nebulae seems to have received a definite answer. The evidence shows clearly that in each of the objects investigated the spiral arms are trailing as the nebula rotates. This result is of fundamental importance in theories of the origin and dynamics of stellar systems.

Completion of construction of the 200-inch telescope at California Institute of Technology has been somewhat retarded by pressure of defense research activities, but we continue to cooperate closely in this program, and in consideration of plans for future operation of the giant telescope. In accordance with agreement reached in 1936, tapering financial support which the Institution has provided for the seismological program at California Institute will terminate this year.

The Geophysical Laboratory has been concerned with investigation of the radioactive content of rocks as a vital factor in many geophysical problems, and as a part of this undertaking determination of radioactive elements in deep-sea cores obtained by Piggot from the Caribbean Sea has developed new and fundamental relationships. In this connection also a special study of radioactive elements in sea water has been carried out during the past year. Ultrabasic, deep-seated rocks make up the fundamental material of the earth's structure, and the whole problem of the ther-

mal conditions of the earth depends largely on the radioactive content of certain of these rocks. It has now been possible to initiate a cooperative study concerning determination of age and heat production relating to rock formation. The equipment for studying silicate minerals in the presence of water at high temperatures and pressures such as prevail deep within the earth has produced a variety of interesting results. This apparatus is essentially an electric furnace within a strong closed chamber in which materials can be exposed to the action of steam at pressures of several thousand pounds and at temperatures far above a red heat. In the course of some experiments on solubility and melting point the formation of clear quartz crystals at a fairly rapid rate was observed. Other arrangements of the apparatus caused an unusual deposit of minerals formed by a solution of material in the vapor phase, followed by deposition in another part of the furnace. One of these minerals was sillimanite, which formed long needles of good size. This is the first time that this mineral has been obtained artificially, and it is probable that the manner of its formation in nature is similar in some respects to that here observed.

Further progress in studies on photosynthesis is reported from the Division of Plant Biology. Recent research relating to the chemical mechanism of the photosynthetic process has necessitated a considerable revision of the older set of hypotheses in regard to the chemical interactions involved. Refinement of existing methods of chemical analysis of the precise nature of the product formed by photosynthesis is being undertaken, and new materials are being subjected to photosynthetic measurements, including certain diatoms under culture. All lines of evidence, morphological, ecological, genetical, and cytologi-

cal, are brought to bear on problems concerning the analysis of plant relationships, in studies in the field of experimental taxonomy. These various methods of procedure are serving as effective checks and balances in development of the species concept.

As a result of work at the Department of Genetics, Blakeslee and his associates, by further application of the alkaloid colchicine method in study of the developmental history of the plant, have found that the stamen is evolutionarily a reduced axis and not homologous with a leaf as is the classic belief. A gene mutant type has been located in *Datura* which so closely resembles the peculiar effects of a certain virus disease that further light is thrown on the question whether there are not close similarities between genes and virus particles, the chief difference between the two, perhaps, being in the fact that the virus particle has unlimited powers of multiplication, whereas the gene is imprisoned within a chromosome and can multiply only when the latter divides.

In accordance with the expressed desire of the Trustees of the Institution for the development of an effective program for cooperation between the Department of Genetics and the Long Island Biological Association at Cold Spring Harbor, an agreement was reached whereby Dr. Demerec, Assistant Director of the Department of Genetics, served as Director of the Biological Laboratory of the Association during the summer of 1941, and Dr. Corner served as Chairman of a scientific advisory committee for the Biological Laboratory program. This arrangement led to a symposium at Cold Spring Harbor on the subject of the gene and chromosome, which attracted a large group of scientists, and which was followed by the annual meeting of the Genetics Society of Amer-

ica. Plans for continuation of such effective cooperation are being formulated in connection with the Institution's program of research at Cold Spring Harbor for next year.

The program of the Department of Embryology contemplates an increased use of physiological, physical, and chemical methods in expansion of the experimental studies of mammalian embryology. Whatever work is undertaken in the future, however, will be intimately and soundly based upon the understanding of the form and structure of the human embryo which has so remarkably and effectively grown out of the past activities of this department. Dr. Streeter is now engaged in classifying and summarizing the results of these morphological studies on the development of the early human embryo, in fulfillment of one of the original purposes for which the Department of Embryology was established. The full statement of the objectives of the Department is presented by the new Director, Dr. Corner, after a year of study and consultation with his colleagues, during which time the aims of the program of research have become focused, although so defined as to admit of adaptation as conditions and opportunity may warrant.

Despite cooperation in defense research, which has required attention of staff members of the Nutrition Laboratory, work at the Laboratory has progressed in development of instrumental technique and in cooperative studies of carbohydrate metabolism with reference to diabetes.

Dr. Kidder reports the interesting circumstances surrounding the discovery of ancient footprints in a stratified formation in Nicaragua, which was previously reported to the Trustees. Investigation is being extended in the attempt to learn, if possible, more about the individuals who made these tracks, and when they made

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them. Work has proceeded at the ruins of Copan, Honduras, where extensive and necessary repairs are being completed preparatory to the inauguration of a brief but intensive program of archaeological study. Continuation of humanistic studies in Middle America has placed the Institution in an unusually favorable situation to cooperate effectively in various types of scholarly effort being undertaken in this region by numerous agencies.

Fortunately the Institution has been privileged, even under somewhat adverse conditions, to continue its cooperation with a number of other agencies in furthering fundamental studies having direct relation to its major projects. Comments by Directors on such subjects will be found in the Year Book, as well as independent reports from some of the investigators who have worked upon cooperative problems during the past year.

REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

ASTRONOMY

*Mount Wilson Observatory
Special Projects*

TERRESTRIAL SCIENCES

*Geophysical Laboratory
Department of Terrestrial Magnetism
Special Projects*

BIOLOGICAL SCIENCES

*Division of Plant Biology
Department of Embryology
Department of Genetics
Nutrition Laboratory
Special Projects*

HISTORICAL RESEARCH

*Division of Historical Research
Special Projects*

MOUNT WILSON OBSERVATORY

Pasadena, California

WALTER S. ADAMS, *Director*

The effect of the war and of the vital demands of national defense has been felt strongly in some of the activities of the Observatory during the year. Its immediate contributions have been through the time and thought devoted by several members of its staff to research projects, mainly of an optical nature, and the development and construction of experimental apparatus in the optical and instrument shops. Although the total effort expended in these directions has been much less than that of some other departments of the Institution, there is reason to expect that certain of the results attained will be of very appreciable value in several of the problems of national defense.

As a member of the Instrument Section of the National Defense Research Committee, Dr. Dunham has been extremely active in the study of the many investigations initiated by the Section and has given most of his time to this work. Dr. Adams, also a member of this Section, and Dr. Anderson of the Observatory staff have aided in the projects assigned to the group in Pasadena, and the members of the departments of design and optical and mechanical construction have cooperated notably.

In a period of disruption of communications and great reduction in scientific activity in the countries of continental Europe, the Observatory has attempted through its connections with the International Astronomical Union to support and encourage the work in progress and to maintain the structure of the Union so far as possible unimpaired. Communications with scientific men in England have been of the greatest value in this endeavor.

Although somewhat handicapped by the stormiest winter in the history of the Observatory, the scientific work has been continued actively, and interesting results have been obtained in several of the major fields of investigation. The sunspot maximum is well past, but spots are still numerous and studies of their magnetic fields, of the character and motions of eruptive prominences, and of solar outbursts and other phenomena related to the sun's activity have formed an important part of the observational program. A new polarizing monochromator built up of a series of quartz plates has proved most efficient for many of these observations. Especially interesting is the additional evidence that the motion of eruptive prominences changes not uniformly but by a set of abrupt transitions in which there may be an integral numerical relation between successive steps. One of the largest solar prominences ever photographed, extending outward from the edge of the sun to a distance of 500,000 km, provided some of the data for this investigation.

It is well known that the magnetic field of the earth is subject to fluctuations in a period of 27 days, the rotation period of the sun. To account for this effect the hypothesis has been proposed that certain areas on the sun are the source of charged particles affecting the earth's field. An attempt to identify these hypothetical areas with those covered by calcium clouds (*flocculi*) on the sun shows a considerable degree of agreement, although some prominent cases are discordant. The problem is of sufficient interest to warrant additional study.

Spectroscopic investigations have in-

cluded the extension of the table of solar wave lengths into the infrared, a work now nearing completion; studies of sunspot spectra in the same region; ultraviolet photographs near the limit of the solar spectrum made through a pair of quartz plates and crossed polarizers which produce a clear background; and the beginning of an extensive series of measurements of the sun's general magnetic field with a Lummer plate and special analyzer. This new and promising method of attack upon the exceedingly difficult problem of the sun's field is most welcome.

In the field of stellar distances and motions, measurements of position have yielded distances for several close neighbors of the sun, including one star whose intrinsic brightness is about one-fifty-thousandth that of the sun. Nearly 30 new members of the Pleiades cluster have been discovered, a result of particular interest as bearing on the question of the relative numbers of stars of different luminosities.

The proper motions of stars have been utilized in several investigations of the amount and direction of the space motions of certain groups or types of stars and the calculation of their absolute luminosities. An important class of long-period variable stars of low temperature is found to have luminosities quite comparable with those of nonvariable stars of the same spectral type, though showing a marked dependence of luminosity on period. Variables of short period have luminosities about two magnitudes brighter than those of long period. Two similar investigations have given the progression in luminosity of the stars of highest temperature (O to B₅) and the average luminosity of the important class of giant K-type stars. The latter determination is of especial value for comparison with results derived from spectral criteria.

Photoelectric measures of the colors of stars near the north pole of rotation and

the two poles of the galaxy have led Stebbins and Whitford to the important conclusion that the sun lies in a fairly uniform absorbing layer of interstellar material, not more than 1700 light-years thick, which produces a total photographic absorption of about one magnitude per 3300 light-years. The absorption is found to vary inversely as the wave length over the entire range from ultraviolet to infrared, thus indicating a high ratio of total to selective absorption.

Two investigations in photographic photometry have been the extension of the magnitudes in certain Selected Areas to photographic magnitude 20.5 and the completion of the determination of the magnitudes and colors of 2200 stars north of +80° declination. A detailed analysis of the color indices and spectral types of several hundred of these northern stars leads to the conclusion that among the brighter stars of early spectral type the color indices are not wholly independent of magnitude.

In the broad field of stellar spectroscopy, investigations have been numerous and varied. The need for observing fainter and fainter stars or for applying higher dispersion to the brighter stars has required the use of every possible means for economizing light and utilizing it most effectively. This has affected the design of spectrographs and has led to such improvements as the "image slicer" invented by Dr. Bowen, of the California Institute of Technology, nonreflecting thin films on the surfaces of lenses and prisms, and bright gratings and Schmidt cameras. The general result has been a marked gain in efficiency and the possibility of observing stars previously beyond reach.

Variable stars of different classes have long been objects for intensive spectroscopic study at Mount Wilson. An important research on about 300 stars of the long-period class has recently been completed

and the results have been analyzed. The residual radial velocities are found to be exceptionally high and to exhibit a group motion in a direction opposite to that of the galactic rotation of the solar group of stars. A well marked relation is found to exist between velocity and period of light-variation—another illustration of the remarkable connection between the physical properties of stars and their motions which is as yet quite without explanation.

Related to the previous investigation is a study of the spectra of more than 100 M-type stars of irregular light-variation but without emission lines. They show large residual radial motions, little concentration toward the galaxy, and but slight variation of velocity with change of light. Their luminosities approximate those of the normal long-period variables.

Physical studies of the spectra of variable stars of different classes have led to the discovery of some remarkable peculiarities in individual stars. The presence of emission lines of calcium in one or two eclipsing variables and the differences in radial velocity indicated by these lines suggest the presence of calcium envelopes about these systems. Further observations of two of the brighter Cepheid variables with exceptionally high dispersion confirm the anomalous behavior of the H and K lines of calcium previously discovered and show marked differences in the behavior and displacement of several absorption lines dependent upon the phase of light. The striking irregularities in the intensities of certain members of the emission lines of hydrogen in long-period variable stars find a probable explanation in the hypothesis that such lines are produced at a low level in the stellar atmospheres and are affected by the absorption of overlying gases. All these observations and many others emphasize the necessity for analyzing the atmospheres of giant stars according to level and even

considering the influence of semidetached envelopes or shells surrounding the stars.

Observations of early-type stars with emission lines in their spectra have been continued, and of especial interest is the determination of the spectral type of a number of very faint exceptionally blue stars situated far from the galactic plane. The important classes of N- and R-type stars have been studied with especial reference to the bands in their spectra. A previously unidentified system of bands in the red region is almost certainly due to the Ca_2 molecule, and another band in the same general region which seems to be correlated in intensity with the isotope bands of carbon may well be due to $C^{13}N^{14}$.

The discovery of a very faint interstellar line close to the position of the strongest ultimate line of neutral iron at $\lambda 3720$ affords the first reasonably definite evidence of the presence of iron in interstellar gases. The intensity of the line indicates a concentration of little more than one atom of neutral iron to each cubic meter of space. Another extremely faint line due to cyanogen gas, of slightly longer wave length than the principal line, has been recognized in the spectrum of ζ Ophiuchi. The measured intensities of the lines of both CH and CN have been used in a calculation of the numbers of molecules present in interstellar space and lead to a value of the general order of one molecule per cubic meter.

Although the number of stars observable with the dispersion adequate to show faint interstellar lines is very limited, it seems clear from existing results that in general one class of clouds of interstellar gas is characterized mainly by molecular absorption and a second class mainly by atomic absorption. In clouds showing very strong atomic absorption, the H and K lines normally seem to be represented by several

components, an effect probably due to separate masses of gas with different radial motions.

Several of the investigations of the year on nebulae within our galaxy have dealt with nebulous shells about novae. One of these, around Nova Aquilae 1918, is 45" in diameter but very faint. Observations made since 1922 can be represented by the expansion, at a rate constant since the outburst, of a single shell of considerable thickness. The distance of the star derived from the rate of expansion and the radial motions is about 1400 light-years. Nova Herculis 1934 has also been observed spectroscopically. The star is involved in a small bright elliptical shell which shows complex emission lines. The rate of expansion, if the separation of the lines is due to Doppler effect, is about 300 km/sec.

A most interesting discovery is that of a small fan-shaped nebula within 1' of the position of the bright nova of 1604 (Kepler's Nova). It was found on red-sensitive plates and is extremely faint in blue light, probably because of strong space absorption in this region. Kepler's estimates of brightness follow closely the normal light-curve of one class of supernovae, and it appears highly probable that the nebula forms the remnant of a supernova in which the range in brightness exceeded 20 magnitudes. This would make the third supernova in the galactic system within the past 900 years.

The Crab nebula, believed to be the remnant of the supernova of 1054, is found to consist of two kinds of nebulosity, one which is diffuse in character, forming the main mass, and the other of filamentary structure, surrounding this mass. The spectrum of the diffuse nebulosity is purely continuous, whereas that of the filaments consists of emission lines. The emission spectrum may be due to excitation by the

continuous spectrum of the diffuse nebulosity, but the source of the continuous spectrum itself is wholly uncertain.

One of the very important but at the same time difficult questions relating to extragalactic nebulae is the direction of motion of the arms in spirals. Observations made during the year show definitely that in two spirals the arms are trailing as the nebulae rotate. The fact that the direction of rotation with respect to the spiral patterns is the same for the 10 nebulae for which data are available makes it at least probable that the arms are trailing in all spirals.

Sufficient spectroscopic observations of extragalactic nebulae on a larger scale than heretofore have now been collected to make possible a beginning of the study of individual lines and contours. In double nebulae, improved data indicate differential radial velocities less than 60 km/sec for both close and wide pairs and suggest that the mean mass of nebulae may be less than 10^{10} suns. Emission lines in the nuclei of a few nebulae have been studied in detail. In certain nuclei the lines are 100 angstroms wide and show a great diversity in structure with marked differences among different elements.

The application by Stebbins and Whitford of a new photoelectric photometer to the colors of nebulae indicates that these systems are mixtures of stars of different colors. The determination of the proportion of stars of different types in the brighter nebulae will be of great interest and significance.

Definitive light-curves have been determined for several supernovae. Those for stars of spectral group I are very homogeneous, becoming linear about 100 days after maximum of light. The curves for stars of group II show occasional halts on the descending branch and may in sev-

eral respects differ considerably one from another. The absolute photographic magnitudes of the two groups at maximum of light are, respectively, —14.05 and —11.8 (upper limit). The available data suggest that the frequency of stars of group II may be six times that of group I. Whether the group II stars form a physical group separate from normal novae is as yet uncertain.

The spectra of four supernovae have been studied during the year. One of these is of group I, two are of group II, and the fourth, which definitely shows absorption lines, probably of hydrogen and calcium, may perhaps best be assigned to group II as well.

In the physical laboratory the study of the complex spectra of rare earths has been continued, and wave-length measures and temperature classification for gadolinium have been completed from observations with the electric furnace. The very rare element thulium has also been studied and more than 350 lines have been classified according to temperature. Several lines of this element probably appear as very faint lines in the solar spectrum.

Aided by the laboratory data, Dr. Russell is engaged on a term analysis of neutral gadolinium and, in collaboration with Dr. Albertson and Miss Davis, has completed an analysis of ionized europium. All the stronger lines of europium, and most of those of moderate strength, have been classified. These include all lines of astrophysical importance.

Computations of the numbers of atoms in stellar atmospheres based on the measured intensities of spectral lines require a knowledge of certain statistical factors, known as "f-values," for the lines involved. Measurements of these important quantities are in progress in the physical laboratory, and relative values for numerous lines

of iron, titanium, and other prominent elements have been derived. *Absolute f*-values have also been determined for about a dozen lines of neutral iron.

The usual method of testing parabolic mirrors during figuring requires the use of a plane mirror with a radius considerably more than one-half that of the mirror to be tested. For very large mirrors this becomes a serious consideration. To avoid the necessity of figuring a plane mirror some 10 feet in diameter to test the 200-inch mirror, Anderson and Ross have devised a method which utilizes the center of curvature of the mirror to be tested instead of its focus. A simple lens, 10 inches in diameter, with a rather large constant of spherical aberration, is placed on the axis of the 200-inch mirror about 60 inches inside the center of curvature. The lens and a slightly deformed correcting plate used with it are so figured that their combination insures exact coincidence of a monochromatic image from any zone of the lens with the intersection of the normals to the corresponding zone of the mirror. Imperfections in the surface of the mirror may then be detected by the usual knife-edge test. One great advantage of the method is that the entire surface of the mirror is visible throughout the test.

Several sources of accidental error in the smaller ruling machine have been eliminated, including the errors of the plate-carriage ways, which are now accurate to about one wave length. The machine is at present being reassembled. Additions to the instrument include improved adjustments and support for the ruling diamond, and considerable attention has been given to the mechanism for shaping the diamond points. Several small gratings have been ruled with each of the two machines, including some of special form and unusual spacing.

STAFF AND ORGANIZATION

RESEARCH DIVISION

Solar Physics: Seth B. Nicholson, Harold D. Babcock, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond, Louise Ware.

Stellar Parallaxes and Proper Motions: Adriaan van Maanen, Ralph E. Wilson, A. Louise Lowen.

Stellar Photometry: Walter Baade, Mary C. Joyner.

Stellar Spectroscopy: Walter S. Adams, William H. Christie, Theodore Dunham, Jr., Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson, Ada M. Brayton, Cora G. Burwell, Dorothy J. Carlson, A. Louise Lowen.

Nebular Photography and Spectroscopy: Edwin Hubble, Walter Baade, Milton L. Humason, Rudolph Minkowski, Dorothy J. Carlson.

Physical Laboratory: Arthur S. King, John A. Anderson, Robert B. King.

Editorial Division: Paul W. Merrill; Elizabeth Connor, librarian; Alice S. Beach, secretary and stenographer.

In addition to his research in stellar spectroscopy, Alfred H. Joy has acted as Secretary of the Observatory.

RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry . Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell, although unable to visit Pasadena during the year, has devoted much time to the term analysis of spectra investigated in the physical laboratory. Dr. Seares has continued his photometric investigations, and especially his studies of colors and magnitudes of stars in the north polar regions. Dr. Stebbins, accompanied by Dr. A. E. Whitford, of the University of

Wisconsin, spent the summer months of 1940 on Mount Wilson measuring colors of stars and nebulae with his photoelectric photometers. Dr. Stebbins returned to Pasadena in June 1941 to continue this work.

TEMPORARY ASSOCIATES

Dr. John C. Duncan, Director of the Whittier Observatory, made photographic observations during July and August 1940 of several nebulous areas in the southern Milky Way and a few extragalactic nebulae. Dr. Toshio Takamine, of the Institute of Physical and Chemical Research at Tokyo, who has been investigating the far ultraviolet absorption spectra of gases in the Pasadena laboratory with the assistance of Dr. Y. Tanaka, returned to Japan in June 1941. Mr. Harold Weaver, of the University of California, aided Baade during the summer months of 1940 in the extension of the photographic scale of stellar magnitudes to very faint stars, and returned to Pasadena in June 1941 to continue this work. Dr. Carl K. Seyfert, National Research Fellow, has been at the Observatory since September 1940, engaged in a study of emission lines in the spectra of extragalactic nebulae.

Many other scientific visitors were at the Observatory for shorter periods of time.

INSTRUMENT CONSTRUCTION

Design: Edgar C. Nichols, Harold S. Kinney.

Optical Shop: John S. Dalton, Donald O. Hendrix.

Instrument Shop: Albert McIntire, foreman; Elmer Prall, Myo C. Hurlbut, Fred Scherff, Oscar Swanson, Albert Labrow, Donald W. Yeager, machinists; James Chapman, pattern maker; Harry S. Fehr, cabinet maker.

OPERATION AND MAINTENANCE

Office: Anne McConnell, bookkeeper; Gladys Adamson, telephone operator and stenographer.

Operation: Ashel N. Beebe, superintendent of construction; Sidney A. Jones, engineer; Kenneth de Huff, assistant engineer; Thomas A. Nelson, Earl Karr, Glenn C.

Moore, Boyd Thompson, night assistants; Anthony Wausnock and Mrs. Wausnock, stewards; Emerson W. Hartong, driver; Charles Dustman, Arnold T. Ratzlaff, Lester Shade, janitors.

Several of the individuals whose names are listed above have been associated with the Observatory only a part of the year.

OBSERVING CONDITIONS

The past year was noteworthy for the extremely heavy precipitation during the winter months, the greatest since the establishment of the Observatory. A total of 74.02 inches was recorded. The winter was exceptionally mild, however, with a minimum temperature of 26° F, and only 18 inches of snow. Although the number of cloudy nights was larger than usual, conditions for observing when the sky was clear were better than normal, probably because of the smaller range in temperature.

The accompanying table shows the distribution of observing nights at the 60-inch telescope.

During the year about 9000 visitors attended the public lecture given each Friday evening at the Auditorium and made visual observations with the 60-inch telescope.

MONTH	OBSERVATIONS		
	All night	Part of night	None
1940:			
July.....	26	5	0
August.....	30	1	0
September.....	23	7	0
October.....	19	7	5
November.....	13	10	7
December.....	8	6	17
1941:			
January.....	11	6	14
February.....	3	7	18
March.....	11	9	11
April.....	9	10	11
May.....	19	9	3
June.....	22	6	2
Total.....	194	83	88
Mean 29 years.....	204	85	75

SOLAR RESEARCH

SOLAR PHOTOGRAPHY

Solar photographs were made by Hickox, Hoge, Nicholson, and Richardson on 272 days. The approximate number of exposures of each kind was as follows:

Direct photographs	588
<i>Ha</i> spectroheliograms of spot groups, 60-foot focus	800
<i>Ha</i> spectroheliograms, 18-foot focus..	1,160
<i>Ha</i> spectroheliograms, 7-foot focus..	24,000
K2 spectroheliograms, 18-foot focus..	1,108
K prominences, 18-foot focus.....	984

SUNSPOT ACTIVITY

During the calendar year 1940, solar observations were made at Mount Wilson on 322 days, on all of which spots were visible. The monthly means of the numbers of groups observed daily for the past two and one-half years are shown in the first table on the following page.

In 1940, 371 sunspot groups were observed, 94 less than in 1939. The southern hemisphere was again the more active, the

difference between the two hemispheres being 29 groups, about the same as in 1939.

MONTH	DAILY NUMBER		
	1939	1940	1941
January.....	8.4	4.3	4.8
February.....	7.8	5.2	5.5
March.....	8.1	7.7	5.0
April.....	10.8	6.5	2.7
May.....	11.4	5.3	3.1
June.....	10.2	8.3	4.7
July.....	7.5	6.9	...
August.....	8.5	9.2	...
September.....	9.0	5.8	...
October.....	8.1	5.3	...
November.....	6.7	6.8	...
December.....	5.7	6.5	...
Yearly average....	8.5	6.5	...

SUNSPOT POLARITIES

When possible, the magnetic polarities in each spot group have been observed at least once. The accompanying table indicates the number of spot groups classified from July 1, 1940 to June 30, 1941. "Regular" groups in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

HEMISPHERE	POLARITY		
	Regular	Irregular	Unclassified
North.....	122	4	42
South.....	119	2	39
Whole sun.....	241	6	81

ERUPTIVE PROMINENCE OF SEPTEMBER 14, 1940

This prominence, photographed by Hickox with the 13-foot spectroheliograph,

was ejected at an angle of 55° to the solar radius, an angle exceeded in only one other recorded case. The prominence shot out to a distance of 500,000 km, moving with a velocity which began at 22 km/sec and suddenly increased to 74 km/sec. This is the 62d eruptive prominence for which adequate velocity data have been secured.

The fact that this prominence was associated with a nearly extinct spot group is in accord with previous observations that maximum chromospheric activity in the neighborhood of a sunspot group frequently occurs in its initial and final stages of development.

THE TEMPERATURE OF A PROMINENCE

Visual measurements by Pettit of the widths of $H\alpha$ and $H\beta$ in quiescent prominences (in which turbulent motions are small) and in the water-cooled discharge tube have been continued photographically at the 150-foot tower in the second-order spectrum with various slit widths and image densities. These show that, after correction for slit width, the line width of $H\alpha$ in the prominence is 0.66 Å, and in the tube at 18° C, 0.15 Å. This gives a prominence temperature of 5730°. The line width in the chromosphere is found to be 1.76 Å.

THE INTERFERENCE POLARIZING MONOCHROMATOR

The Lyot telescope was the first instrument to make prominence observations possible without spectroscopic equipment or an eclipse, but its success depends upon high elevations and clear sky. The interference polarizing monochromator, first designed by Öhman and later applied to the sun by Evans, has the advantages of the Lyot instrument without its restrictions, and is an attachment to, rather than a substitute for, a telescope.

One of these instruments has been constructed by Pettit. It consists of a system of seven quartz plates, eight polaroid sheets, and two red glass filters mounted between the components of a projector objective in a temperature-controlled box. A 35-millimeter motion-picture camera attached to the monochromator is used to photograph the prominences, and visual measurements are made with a filar micrometer. Guiding is done by a right-angle pellicle eyepiece.

While constructing the monochromator, Pettit measured radiometrically, in integrated $H\alpha$ light, the transmission of polaroid film where one surface reflection is involved, and found it to be 50 per cent. For polarized light vibrating parallel to the axis of the polaroid, the transmission is 82 per cent.

When the instrument is attached to a 6-inch telescope with the image magnified to equal that given by a 40-foot telescope, the exposures vary from 8 seconds for "Background X" film to $1/25$ second for "H" film. Arrangements are being made to use the instrument on the mounting of the 20-inch reflector with the aid of an image-forming objective.

Since its completion the instrument has yielded interesting observational results, a few illustrations of which are given below.

Visual measurements on a solar "surge" on January 3 showed the velocity diagram typical of these objects—rapid initial advance, sudden changes in velocity, and slower final retreat. Its maximum extension was 115,000 km.

On May 8 a sunspot prominence of type IIIb was photographed. More than 400 successive exposures were obtained, and of these several showed formation of loops at the crest and a downward rush of chromospheric matter along both branches. The entire fountain-like object was immersed in a faint haze which seemed to have a granular structure. When the film is pro-

jected as a motion picture this granular structure is seen to be expanding outward from the spot area while the prominence streamers move into it. The great light-efficiency of the instrument made possible for the first time the detection of this type of structure.

On May 21 a tornado was photographed which showed distinctly the action taking place within the spiral trunk. The spiral rotated while matter moved upward along the trunk and was ejected from the top. The greater part was ejected vertically, some continuously and some discontinuously, but a part returned along a lateral branch to the chromosphere.

CALCIUM FLOCCULI AND SOLAR M-REGIONS

An attempt has been made by Richardson to identify persistent bright calcium flocculi with the solar M-regions (areas postulated to be the source of charged particles causing the 27-day recurrences in terrestrial magnetic activity). Sketches of the bright flocculi on the calcium spectroheliograms, arranged in successive rows of 27 days each, have been compared with corresponding charts showing recurrences in magnetic activity. Identification has been attempted only for years near minimum, and for three exceptionally prominent sequences in magnetic activity. The bright flocculi are found to combine the characteristics deduced for the hypothetical M-regions more completely than any other known solar phenomenon, but identification is rendered doubtful by lack of agreement in certain prominent cases.

Since it is believed that the hypothetical active regions could not escape detection in those parts of the solar atmosphere accessible to observation, the results obtained indicate that the M-regions may occur in a region not readily observable; for example, below the photosphere or in the corona.

INFRARED SOLAR AND SUNSPOT SPECTRA

Babcock has completed the remeasurement of the lines in the solar spectrum in the region $\lambda 10450$ to $\lambda 11200$ with the equipment at the Hale Solar Laboratory. The results confirm the earlier data, but the weight of the final wave lengths is now greatly increased and some new lines have been observed. Between $\lambda 12200$ and $\lambda 13500$ the measurements already made will be published without further refinement, since their improvement is difficult, the laboratory data are meager, and water-vapor absorption is responsible for most of the lines thus far recorded. Manuscript covering 700 Å at the beginning of the table has been sent to the Princeton Observatory for final preparation.

In sunspots the spectra of *Cr*, *V*, *Ti*, *Si*, and *C* have been studied on infrared plates, where comparison with the solar disk brings out striking evidence of the lower temperature in spots. These and similar results are being used both in the *Mount Wilson-Princeton Infrared Solar Table* and in the revision of Miss Moore's *Multiplet Table*.

ULTRAVIOLET SOLAR SPECTRUM

Even with the best gratings and filters, solar spectrograms near $\lambda 3000$ are fogged by scattering of the relatively intense radiation in the nearer ultraviolet. Babcock has found that the expense and inconvenience of overcoming this difficulty by the use of preliminary dispersion can be avoided with the aid of broad interference bands in polarized light. Excellent spectra terminating in clear background have been made with a pair of quartz plates between crossed polarizers of a type efficient in the ultraviolet. The thickness and disposition of the quartz plates are calculated for the transmission of a wide band in the spectrum having a maximum intensity at $\lambda 2975$ and

a minimum at $\lambda 3250$, a spacing controlled by the properties of the quartz plates.

GENERAL MAGNETIC FIELD OF THE SUN

The iron lines $\lambda\lambda 6173$, 6302 have been measured by Babcock on 50 spectrograms made with the Lummer plate and special analyzer at solar latitudes N 45° and S 45° . The observations are evidently significant, and the series has been continued and is being followed by a second involving two fainter lines in the green. More than 120 new spectrograms have been obtained and measurements are under way. Such a program requires a very considerable amount of incidental observing and testing of equipment.

SPECTRAL ENERGY-CURVE OF SUNLIGHT WITH HIGH DISPERSION

The 21-foot concave-grating monochromator with photoelectric cell and amplifier has been modified by Pettit to register on the same scale as the *Utrecht Photometric Atlas*. A quartz filtering monochromator is used to reduce scattered light. Preliminary trials indicate that with a few additional modifications the instrument can be used to compare the *Photometric Atlas* with radiometric registrations.

TRANSIT OF MERCURY

Photographic observations of the transit of Mercury of November 11, 1940, were made by the solar observers. The time of second contact was determined from eye estimates of the planet's image on motion-picture film; from the measured distance between Mercury and the sun's limb on the motion-picture film; and from a series of 16 images taken on a high-contrast emulsion at the 150-foot tower. The mean of all measures gave a time of second contact 16 seconds earlier than that predicted by the *American Ephemeris* for Mount Wilson.

PLANETS AND SATELLITES

A spectrogram of Pluto obtained by Humason on the night of March 23, 1941, with the 2-prism spectrograph and 3-inch Schmidt camera showed a typical solar-type spectrum. In the region between $\lambda 3700$ and $\lambda 5000$ no observable differences from the solar spectrum could be detected with the dispersion employed (230 Å per millimeter at $H\gamma$).

Several high-dispersion spectrograms of the ultraviolet spectrum of Venus have

been taken by Adams and Dunham. A close comparison with the solar spectrum gives no evidence of the presence of formaldehyde bands in the planetary spectrum, an interesting possibility suggested by Dr. Wildt.

Several of the fainter satellites of Jupiter have been reobserved during the year by Nicholson, and improved elements of their orbits are now being calculated by Nicholson and other investigators.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

Of the 16 stars measured by van Maanen for parallax, all but 2 have absolute photographic magnitudes of +10 or fainter. Among these Luyten 789-6, for which a final solution has been obtained, has an absolute magnitude of +16.8, and a faint companion of Ross 513 has a magnitude of +16.2. Wolf 1328 has a parallax of +0''.127. Fifty stars, including 13 companions, are now known which lie within 5 parsecs of the sun, and 127 stars, including 29 companions, between 5 and 10 parsecs.

Three Cepheids and 11 spiral nebulae have been measured by van Maanen for proper motion as part of an extended program including such objects.

Two pairs of plates of the region around Alcyone, taken with intervals of 17 and 19 years, respectively, have also been measured for proper motion. They were obtained at the Newtonian focus of the 100-inch telescope with exposures of 30 minutes or more, and cover a field of 40' by 30'. As a result of the measures, 56 probable members of the Pleiades group have been found, of which 28 were not known previously. The photographic magnitudes of the known stars range from 4.2 to 15.1, those

of the new members from 12.4 to about 17.5. The large number of new stars of magnitudes 15, 16, and 17 makes it evident that the maximum in the frequency-curve has not yet been reached. This is not surprising since the absolute photographic magnitude of the faintest members is about +12, whereas in our immediate neighborhood, as van Maanen has shown, the maximum of the photographic luminosity-curve lies at about +14.5.

Measures of 24 fields containing variables, mainly of the δ Cephei and RR Lyrae classes, have been made by R. E. Wilson in addition to 3 fields measured by van Maanen. Second-epoch plates have now been secured for 58 fields. Of these, 55 have been measured, 44 by Wilson, 16 by van Maanen, and 5 by both. The probable errors are about $\pm 0''.0013$ in each coordinate.

A study of the proper motions of the long-period variables of classes Me and Se by R. E. Wilson shows that their group motion is $0''.014$ per year in the direction $A_0 = 282^\circ$, $D_0 = +45^\circ$, in agreement with the direction usually found for the nonvariable stars of class M. The preferential motion is along an axis directed toward the center of the galaxy. The motions of the Se stars are considerably less than those of Me

stars. The parallactic motions show no correlation with type and period, but the peculiar motions show an increase with both type and period. Distances obtained from comparisons of the angular and radial motions show that the mean luminosities of the Me and Se stars are essentially the same, $\bar{M} = -1.0$, but that the stars with the shorter periods are at least 2 magnitudes brighter than those with the longer periods. A study of the period-luminosity relation for these stars is nearing completion.

COLORS OF A AND B STARS

Stebbins and Whitford have completed photoelectric measures of the colors of A stars near the north pole of rotation and the north and south poles of the galaxy. These and previously measured colors of B stars indicate that the sun is in a fairly uniform absorbing layer in space, not more than 500 parsecs thick, giving a total photographic absorption of about one magnitude per kiloparsec.

They have also finished a program of spectrophotometry of 13 stars to determine the law of reddening by interstellar material. The absorption is found to vary as $1/\lambda$ over the range $\lambda 3500$ to $\lambda 12500$, a result in conformity with a high ratio of total to selective absorption in space.

EXTENSION OF THE PHOTOGRAPHIC SCALE IN CERTAIN SELECTED AREAS

With the cooperation of H. Weaver, final photographic magnitudes down to 20.5 have been derived by Baade for the Selected Areas 57 and 61. Work is in progress on Areas 85, 89, and 45, all of which will be finished before the end of the present season. With the two remaining Areas, 72 and 76, the program will be completed.

MOUNT WILSON POLAR CATALOGUE

The extension of the Polar Sequence by Seares, Ross, and Miss Joyner, which pro-

vides magnitudes and colors of about 2200 stars north of $+80^\circ$ declination, has been completed and the final proofs of the *Catalogue* have been read. The discussion given in the introduction to the volume indicates a very satisfactory internal accordance. Both the scale and the color system seem to be in agreement with those of the international standards. As far as accidental irregularities are concerned, the mean error of a catalogue magnitude is usually less than 0.02 mag.

A supplementary investigation based on the color indices of the Catalogue and the spectral types of several hundred of the stars shows consistency in the results for all classes of stars except those of types B, A, and F which are brighter than the ninth magnitude. For these types the mean color indices, even after allowance for space absorption, are not wholly independent of magnitude. The results suggest an irregularity arising from the poorly defined color system of the brighter stars of the Polar Sequence. The colors of stars of all types show the influence of absorption, the exact amount of which is still to be determined. The quantitative results already announced appear, however, to be of the right order.

LUMINOSITY SEQUENCE FOR STARS OF SPECTRAL TYPES O₅ TO B₅

A study by R. E. Wilson of the mean visual absolute magnitudes of O₅ to B₅ stars, taking into account both the spectral classification and the character of the lines, shows that the presence of diffuse or emission lines in the spectra is not in general indicative of abnormal luminosity. The values of \bar{M} show the following progression: O, -3.7 ; B₀, -3.1 ; B₁, -2.7 ; B₂, -2.3 ; B₃, -1.7 ; B₅, -0.8 . Wolf-Rayet stars have essentially the same mean luminosity as the absorption O stars, and the c stars with emission spectra lie on the

supergiant sequence defined by the normal nonvariable c stars.

ABSOLUTE MAGNITUDES OF GIANT K STARS

Strömgberg has devoted much of his time to statistical studies of the absolute magnitudes of certain classes of stars. The results for the giant K stars have been finished. These stars are of particular interest, both because their internal conditions and mechanisms of heat generation probably differ considerably from those in the main-sequence stars and because enough stars are available for satisfactory determinations of intrinsic brightness.

The mean absolute magnitude of these stars has been found to be about +0.70 and the dispersion around this mean, 0.84. The spectroscopic absolute magnitudes published in *Mount Wilson Contribution No. 511* give practically the same mean value, but the dispersion is only 0.52. Corrections to the spectroscopic absolute magnitudes have been determined for the two cases in which the stars are grouped according to a basis correlated with the internal heat generation, and with conditions in the stellar atmosphere, respectively. The mean errors of the individual spectroscopic absolute magnitudes have been reduced to 0.45.

STELLAR SPECTROSCOPY

The 2-prism spectrograph with collimating mirror, to which reference was made in last year's report, has been placed in active use at the Cassegrain focus of the 100-inch telescope. Early trials showed small deflections depending upon hour angle, which were traced to the mounting of the mirror and the main supporting frame. The mounting was replaced and the frame was greatly stiffened by the insertion of strong tension and compression members between the arms carrying the cameras and the collimating mirror. The spectrograph is now giving excellent definition with cameras ranging in focal length from 3 to 18 inches and exposure times of several hours. Its efficiency is high, spectra of stars of photographic magnitude 12.5 being obtained on a linear scale of 110 angstroms per millimeter at $H\gamma$ with an exposure of 1 hour under good observing conditions. The instrument is proving most valuable for observations of supernovae, faint variable stars, and stars of large proper motion.

The device resembling in principle the van Cittert monochromator, designed by

Dunham for providing calibration spectra in the ultraviolet region for the coudé spectrograph of the 100-inch telescope, has been constructed and is now in use. A special tungsten ribbon lamp, designed and constructed by the General Electric Company, has been used as the source of light. It is effective to $\lambda 3000$ and, when operated from a voltage regulator, gives very constant intensity.

Another important improvement has been made by Dr. Bowen and Dunham for use in connection with the image slicer. A small quartz lens above the image slicer focuses the star's image on the rulings of the grating, and diffraction at the slit spreads the light sufficiently to provide for the utilization of nearly the full resolving power of the grating. In this way one of the most troublesome characteristics of the spectra taken with the image slicer—the horizontal absorption strip corresponding to the central "blind spot" in the telescope—has been almost completely eliminated.

About 1530 spectrograms have been obtained with the various instruments during the year.

RADIAL VELOCITIES

Merrill has brought to a close a long program devoted to spectroscopic measurements of the motions of long-period variables, begun at Ann Arbor, Michigan, in 1913 and carried on at Mount Wilson intermittently since 1919. The total number of spectrograms obtained approximates 1100, of which 438 are of objects fainter than magnitude 8.9. The number of variables observed is about 285.

Much supplementary research has been required to find the best method of correcting measurements of the bright lines for the systematic displacements of these lines relative to the absorption spectrum, and to make sure that the final results correspond closely to the actual stellar motions.

A catalogue of the velocities of 305 variables of spectral types Me and Se, combining all known measurements, has served as the basis of a statistical discussion of the galactic motions of these stars. The residual radial velocities, computed by applying the corrections for solar motion, are decidedly high, the arithmetic mean being 36 km/sec. It is surprising to find a well marked relation between velocity and period of light-variation. The average residual velocity decreases steadily from 80 km/sec for a group of 27 stars with periods between 150 and 200 days to 17 km/sec for 35 stars with periods greater than 400 days. The difficulty of explaining the relation between the intrinsic physical properties of these stars and their motions calls attention to the limitations of our present knowledge concerning stellar evolution.

Like other stars with high random velocities, the long-period variables exhibit an apparent group motion in a direction opposite to that of the galactic rotation of the solar group of stars. The group motion increases approximately as the square

of the residual velocity up to 60 km/sec for a group of 163 variables having an average residual velocity of 47 km/sec. The computational results are in harmony with the accepted interpretation that the velocity asymmetry of high-speed stars is an effect connected with galactic rotation. The so-called high-speed stars are those which, in their galactic orbits, have circular velocities actually *less* than that of the solar group of stars.

During the year an average of about three nights a month has been devoted by Strömgren to observations of the brighter stars in the Selected Areas with the 60-inch telescope. The reduction in the loss of light at the surfaces of the optical parts, due to the coating of the lenses and prisms, has made it possible to use the 18-inch camera for nearly all the stars without appreciable increase in the average exposure time. At present, in a program of 297 stars distributed among the Selected Areas north of 30° south declination, three or more satisfactory spectrograms have been obtained for each of 157 stars. Of those remaining, two spectrograms have been obtained for 53 stars, and one spectrogram has been obtained for 56. Only 31 stars are as yet unobserved.

Measurements of the radial velocities of a considerable number of A- and B-type stars in special regions of the sky, observed at the request of Dr. Bok of the Harvard College Observatory, have for the most part been completed by Christie. The spectra of several of these stars show interstellar calcium lines. In the Cygnus cloud a group of 16 B-type stars of average photographic magnitude 9.8 has also been observed by Humason.

Sanford has continued his observations of the interesting spectroscopic binary which forms the visual companion of Rigel. The variation in the velocity of Rigel itself has also been investigated with

the aid of spectrograms taken on fine-grained plates.

O. C. Wilson has developed a simple method for deriving mass ratios in spectroscopic binaries showing double lines, without completely determining their orbits. He is now investigating all known binaries of this type, especially with a view to studying the agreement of the mass ratios with the mass-luminosity relationship.

Spectroscopic observations of faint stars of large proper motion have been continued by Joy, Humason, and Adams. Both the spectral types and the radial velocities of these rapidly moving dwarf stars are of exceptional interest.

SPECTRA OF VARIABLE STARS

A study of the spectra of 104 M-type irregular variables without emission lines has been completed by Joy. The chief conclusions are: (1) the stars show little or no concentration toward the galaxy; (2) their residual motions are large; (3) the velocity variation during the cycle of change of light is small; (4) the spectral types are mainly between M₄ and M₈ with a maximum frequency at M₆; (5) in a few stars faint emission lines occur at certain times; (6) the absolute magnitudes approximate those of the Me long-period variables. Associated with these stars is the class known as RV Tauri variables, which show no titanium bands in their spectra at maximum of light. Their average radial velocities are the highest of any group of stars known with the exception of the RR Lyrae variables. Joy is investigating 37 such stars.

Several eclipsing variable stars have also been under observation by Joy. Two of these are of especial interest. A discussion of 31 spectrograms of WW Draconis indicates that the absolute magnitudes of the two stars involved are fainter than

would be given by the mass-luminosity relationship and that they fall between the giants and dwarfs in size and mass. The secondary spectrum is present in absorption but extremely weak. An extraordinary feature of this spectrum is the presence of emission lines (H and K) of calcium which have a smaller velocity range than the absorption lines. This suggests that there is a calcium envelope surrounding the secondary star which is greatly extended by tidal attraction in the direction of the more massive star.

Another striking example of the unexpected peculiarities of stellar atmospheres was found in a spectrogram of RW Tauri taken during total eclipse on October 9, 1940. The hydrogen lines appeared as strong double emission lines whose components are separated by an amount corresponding to 700 km/sec. If this effect is caused by rotation of the atmosphere of the eclipsed primary star, the speed is entirely unprecedented. Further observations will be necessary before conclusions can be drawn.

Peculiarities of the emission lines in the Balmer series, known for a long time in the spectra of Me variables, have been studied in detail by Merrill. One conclusion is that the marked irregularities in intensity are due to the abnormal weakness of certain members, notably H_ε, H_κ, H_μ, and H_ξ. On this assumption the general Balmer decrement does not differ greatly from that of the Be star BD+11°4673 or from that of the hydrogen spectrum observed in the laboratory.

Peculiarities in intensity, structure, and displacement of the bright lines are greatest when the lines first appear; they tend to become less marked as the light of the variable declines after maximum. Much evidence now supports the hypothesis that the bright lines are produced at a relatively low level—perhaps just above the photo-

sphere—and that many of their peculiarities are caused by the absorption of overlying gases.

Further observations on long-period variables include those of Joy on the structure of the emission lines in σ Ceti, mainly with the coudé spectrograph, and of Humason on R Aquarii. The inner nebulosity connected with R Aquarii shows the emission lines found in the star but with different relative intensities. Several additional emission lines, notably $\lambda 3727$, are present in the nebular spectrum. The nebulosity observed is 4" south of the variable.

Measures of the absorption lines of calcium (H and K) in the spectra of the Cepheid variables ζ Geminorum and η Aquilae have been continued by Adams and Joy, and provisional radial velocity-curves based on these lines have been derived for comparison with those from the normal stellar lines. High-dispersion spectrograms taken by Adams with the coudé spectrograph show the presence of faint interstellar H and K in the spectrum of η Aquilae, the first evidence for the existence of such lines in Cepheid variables. Spectrograms taken at maximum and minimum of light also show marked differences of displacement among the normal stellar lines, most of the lines which are noticeably widened at the minimum phase being displaced to the violet with respect to the narrower lines.

Joy has observed in globular clusters the spectra of eight Cepheid variables with periods longer than 6 days. A comparison of these stars with galactic Cepheids should prove of exceptional interest.

EARLY-TYPE STARS WITH EMISSION LINES

The search for stars showing bright lines in their spectra on objective-prism photographs taken with the 10-inch telescope, for

the most part by William C. Miller, which has been carried on by Merrill and Miss Burwell during the past few years has resulted in the listing of several hundred probable bright-line objects. About 60 out of 180 selected stars have been observed with slit spectrographs. They are mainly of type Be, and several show interesting peculiarities. An additional group includes more than 60 faint objects in whose spectra only the bright $H\alpha$ line is visible. Observations with the large telescopes show that one of these is a minute planetary nebula previously unrecognized. It has a high radial velocity, —152 km/sec, and is probably very distant. Another object proves to be a twelfth-magnitude nova, the character of which has been confirmed by Miss Henrietta Swope from photometric records at the Harvard College Observatory.

STARS OF TYPES N AND R

In continuation of his investigations on these types of stars, Sanford has taken some 130 spectrograms during the past year. Included among these are observations of several long-period variables of type N which show spectral changes with phase of light. The variable UV Aurigae at maximum of light shows well marked Swan bands and emission lines of hydrogen, whereas near the minimum of 1940 the Swan bands were absent and the nebular lines $\lambda\lambda 4363$ and 5007, together with helium $\lambda 4471$, were present in emission in addition to the hydrogen lines. In the spectrum of U Cygni a system of bands near $\lambda 6190$ which degrade toward the violet is strong at minimum of light and then grows fainter, disappearing at maximum. These bands are almost certainly due to the $C\alpha_2$ molecule.

An absorption band between $\lambda 6257$ and $\lambda 6274$ has been observed repeatedly in stars of spectral types N and R whenever the isotope band head of $C^{12}C^{13}$ at $\lambda 6168$ is

strong. The $\lambda 6257$ band may possibly be due to the superposition of features of $C^{13}N^{14}$ upon those of $C^{12}N^{14}$ so prominent near this wave length in stars of these types.

FAINT BLUE STARS

The spectra of 25 stars with photographic magnitudes between 12.5 and 15.5, found by Dr. Zwicky on photographs taken with the 18-inch Schmidt telescope on Palomar Mountain to be exceptionally blue, are under observation by Humason. The instrument used is the 2-prism spectrograph with a 3-inch Schmidt camera. Of the regions observed by Zwicky, one is at the north pole of the galaxy and contains several of these objects. In view of the well known tendency of the brighter B-type stars to concentrate toward the galactic plane, the spectra of these faint stars cannot fail to be of interest whether they prove to have the characteristics of white dwarfs or of B stars.

SOME INDIVIDUAL STARS

The large amount of observational material obtained by O. C. Wilson at the 1939-1940 eclipse of ζ Aurigae is under investigation by him and much progress has been made. This remarkable star affords a unique opportunity for detailed study of the atmosphere of a giant K-type star at successive levels above the photosphere.

The velocity-curve of the peculiar early-type star 48 Librae (HD 142983) has been found by Sanford and Merrill to be continuing its upward trend, with the metallic lines and the ultraviolet hydrogen lines showing somewhat larger displacements than those of $H\beta$, $H\gamma$, and $H\delta$. The anomalous line displacements are of unusual interest.

Two other early-type stars with bright hydrogen lines which have been studied

extensively are BD+11°4673, in which Merrill has found that TiO bands are now visible, and γ Cassiopeiae, in whose spectrum certain changes have been followed by Merrill and O. C. Wilson.

INTERSTELLAR LINES

Considerable evidence for the existence of interstellar iron is afforded by the discovery by Dunham in the spectrum of χ^2 Orionis of a very faint line close to the position of $\lambda 3719.949$, the strongest ultimate line of neutral iron in the observable spectrum. The next strongest line is at $\lambda 3859.9$ and has not yet been observed with certainty. The measured intensity of the line at $\lambda 3719$ would correspond to a concentration of a little more than one atom of neutral iron per cubic meter of space. The study is being continued with the aid of spectrograms of high contrast requiring long exposure times.

The presence of $\lambda 3875.77$, the $P(1)$ line of the o,o band of CN calculated by Dr. McKellar, as a very faint interstellar line in the spectrum of ζ Ophiuchi, has been confirmed by Adams. Its intensity, as predicted by McKellar, is approximately one-half that of the $R(1)$ line at $\lambda 3874.00$.

Dunham has measured the intensities of the lines of CH and CN in the spectra of several stars and has used the results in an attempt to deduce the numbers of molecules in the line of sight. Since little is known regarding the absolute absorbing power of molecules, a laboratory study of the absorption spectra of CH and CN in the electric furnace was undertaken with the collaboration of R. B. King. Tentative f -values were derived which were then applied to the stellar observations. Concentrations of the order of one molecule per cubic meter of space were found for each of the gases, a result naturally subject to considerable uncertainty because of probable errors in the f -values.

Spectral observations by Dunham of two relatively near stars, α Virginis and η Ursae Majoris, show the presence in α Virginis of an interstellar K line with an intensity of about 0.0035 E.A. In η Ursae Majoris, however, no such line is visible. The results indicate that in the vicinity of the sun the concentration of $Ca\text{ II}$ amounts to about 2.4×10^{-4} ions per cubic meter in the direction of the constellation of Virgo, but less than one-fourth as much toward Ursa Major.

The relation which seems to exist between the intensities of two groups of interstellar lines has been further confirmed by recent observations. Thus in the spectrum of ζ Ophiuchi, which shows the lines of CH and CN exceptionally well, the unidentified lines at $\lambda\lambda 3745, 3957$, and 4232 are prominent, whereas H and K and the sodium lines are of only moderate intensity, and the $Ti\text{ II}$ lines and $\lambda 4227$ are faint or not visible. In χ^2 Orionis and several

other stars the reverse is true. In general it appears that one class of clouds of interstellar gas is characterized mainly by molecular, the other by atomic absorption.

The use of very high dispersion on the interstellar H and K lines indicates that the complex structure of these lines is normal rather than exceptional. All strong interstellar lines yet observed with the 114-inch spectrograph in the second order of the grating show more than one component, the principal line often being divided into two parts separated by 0.10 to 0.15 Å. The K line in χ^2 Orionis consists of four components, one faint component on either side of a strong double line. It is not yet certain whether these components are all to be ascribed to discrete clouds moving with different velocities, but it seems clear that these observational results may well have application to problems based on the intensities of interstellar lines.

GALACTIC NEBULAE

Studies of galactic nebulosities during the year have centered largely on nebulous envelopes around novae. The principal results are Baade's interpretation of the Nova Aquilae (1918) outburst as a single thick shell expanding at a uniform rate; his discovery of the remnant of Kepler's Nova (1604) and the identification of the outburst as a supernova; and Minkowski's demonstration of the unique physical conditions in the Crab nebula, the remnant of the supernova of 1054.

Other results include Minkowski's collection of spectra of planetary nebulae of low temperature, O. C. Wilson's observations of the nuclei of planetary nebulae, and various programs of direct photography of diffuse nebulosities in which special emphasis is placed on the use of red-sensitive plates.

EXPANDING SHELL AROUND NOVA AQUILAE (1918)

The expanding shell around Nova Aquilae (1918) is now about 45" in diameter, and very faint. Baade has obtained photographs, in $H\alpha$ emission, which will probably represent the last detailed records of the phenomenon. A discussion of the material accumulated since 1922, together with the earlier visual measures, shows that the shell has expanded at a constant rate since the outburst. The direct photographs, together with spectrograms, give a picture of the detailed structure of the envelope, the spectrographic phenomena being readily explained by uniform expansion of the shell. An improved value for the distance, 430 ± 20 parsecs, has been derived by taking into account the finite thickness of the shell.

EXPANDING SHELL AROUND NOVA HERCULIS (1934)

The shell around Nova Herculis (1934), as photographed at the Newtonian and Cassegrain foci of the 100-inch, is now about $3\overset{''}{.}5 \times 2\overset{''}{.}7$. No trace of the former duplicity has been detected. The star, lost in bright nebulosity since April 1935, was photographed in the spectral region $\lambda 5200-5800$, which is relatively free from strong emission. The magnitude of the star at present is $m_{pv}=13.35$.

Spectrographic observations by Humason of the gaseous shell surrounding the nova now show complex emission lines of an interesting character. The two outer components have a mean separation of 9.9 \AA and, on the assumption that the separation is due to Doppler effect, give for the rate of expansion 300 km/sec . A component nearly central between the outer components is also present, and the uneven distribution of the emission within the lines indicates the presence of other weaker components which probably originate from condensations within the shell, each with a different velocity. The ends of the lines appear to curve inward rapidly to the zero position, as might be expected when the separation due to the Doppler effect is large compared with the size of the nebular image.

Visual observations of the nebulous shell at the Cassegrain focus of the 100-inch reflector with excellent seeing showed clearly the elongation of the nebula in P.A. 135° , but no duplicity was noted.

IDENTIFICATION OF THE REMNANTS OF KEPLER'S NOVA (1604)

Baade has found a small patch of nebulosity within $1'$ of the position of the bright nova of 1604 (often called Kepler's Nova) as recently determined by Schlier and Bohme—R.A. $17^h 26^m 45^s$, Dec. $-21^\circ 25' 9$

(1935). The object is fan-shaped, with filamentary structure about $30''$ across. It is extremely faint in the blue, evidently because of heavy space reddening and conspicuous absorption in the area, but the emission image, presumably due to $H\alpha$, is readily seen on red-sensitive plates.

Since no star brighter than $M=18.5$ is found in the vicinity, the range in brightness of the nova ($m_{max}=-2.5$) exceeded 20 mag. and is comparable with that of the supernova of 1054 (Crab nebula). This fact is at present the strongest argument that Kepler's Nova was also a supernova. The suggestion is supported by strong reddening (which implies high luminosity at maximum), and also by the fact that Kepler's estimates of brightness follow very closely the normal light-curve for supernovae of group I.

An attempt by Minkowski, under favorable conditions, failed to register any trace of the spectrum of the nebulosity in the blue. Further investigations will be made in the red during the next observing season.

We can now recognize three supernovae which have appeared in the observable region of the galactic system within the past 900 years. The other novae recorded during this interval seem to have been truly normal novae.

SPECTROGRAPHIC STUDY OF THE CRAB NEBULA

A spectrographic investigation of the Crab nebula, by Minkowski, reveals conditions in this remnant of the supernova of 1054 which are widely different from those in any other known object. The nebula, as suggested by Baade's direct photographs, consists of two kinds of material with quite different properties. The diffuse nebulosity forming the main mass shows a purely continuous spectrum, and the filaments which surround the mass but con-

tribute relatively little luminosity furnish the emission lines.

The study indicates that the filaments are probably excited by ultraviolet radiation from the diffuse nebulosity and not directly by the central star. No acceptable interpretation of the continuous spectrum has been found. It does not represent scat-

tered radiation from the central star because no appreciable absorption can be detected in the nebula. The usual assumptions of free-free and free-bound transitions of electrons lead to values for the temperature and luminosity of the central star which are not compatible with the observational data.

EXTRAGALACTIC NEBULAE

The principal results in the study of extragalactic nebulae are the determination by Hubble of the direction of rotation in spirals, and the first clear evidence of mixtures of spectral types in unresolved nebulae, obtained by Stebbins and Whitford with a new photoelectric photometer. Other results are in the nature of reports of progress and of individual clues which must be followed up by further investigation. In particular, the large-scale spectrograms which Humason is obtaining have opened new possibilities in this field of research.

DIRECTION OF ROTATION IN SPIRALS

In the two spirals NGC 3190 and 4216, Hubble has found that the arms are trailing as the nebulae rotate. This conclusion confirms the preliminary results for NGC 4258 mentioned in the last annual report. Since the ten spirals for which data are available are all rotating in the same direction with respect to the spiral patterns, and the particular direction is now known in at least two cases, it may be assumed as a working hypothesis that the arms are trailing in all spirals.

DIFFERENTIAL MOTIONS IN DOUBLE NEBULAE

A previous attempt to derive nebular masses from orbital motions in double nebulae was unsuccessful because the dif-

ferential radial velocities were less than the uncertainties of the data then available. Improved velocities, by Hubble and Humason, have now reduced the uncertainties to less than half those of the previous data. The mean differential motion in the 20 pairs observed is still undetermined although it is evidently less than 60 km/sec both for a group of close pairs and for a group of wide pairs (mean projected separations of the orders of 4000 and 50,000 parsecs, respectively). The results suggest that the mean mass of nebulae may be less than 10^{10} suns.

SPECTRA OF NEBULAE

About 40 small-scale (500 Å/mm) spectrograms of nebulae have been collected by Humason and Hubble for the study of red shifts and spectral types, in addition to 20 spectrograms on an intermediate scale (220 Å/mm). Spectra on the latter scale are now available for 40 nebulae at various stages in the sequence of classification. The collection is now sufficient for the calibration and interpretation of small-scale spectra and for the selection of suitable objects for study on larger scales. Humason has initiated the next phase of the program by obtaining several spectra with scales of 110 and of 65 Å/mm at $H\gamma$. These spectrograms permit the study of individual lines and line contours, and thus open to exploration a quite new field whose full significance cannot yet be estimated.

NUCLEAR EMISSION IN SPIRALS

A special investigation of emission spectra in the nuclei of nebulae has been carried on by Seyfert. The objects NGC 1068, 3516, and 4151 have been studied in detail, and less extensive data have been obtained for several other examples of the same type. The emission lines are those found in planetary nebulae and have similar relative intensities, but they are greatly broadened, presumably by Doppler effects.

NGC 3516 is unique in that the N₁ and N₂ bands are relatively narrow (less than 15 Å), whereas the hydrogen bands are very broad (order of 100 Å). In NGC 1068, the bands are 40 to 60 Å wide, and three of the strongest, N₁ and N₂ [O III] and 3869 [Ne III], appear to be double, with the maxima separated by 4 or 5 Å. The bands in NGC 4151 are about 15 Å wide, and the hydrogen bands, at least, appear to be centrally placed on shallow bands 80 to 90 Å wide. The interpretation of these and other pertinent data is now in progress.

A P-CYgni-TYPE VARIABLE IN M 33

In the course of a study by Hubble of supergiant irregular variables in neighboring stellar systems, the spectrum of an individual star in a spiral was for the first time recorded on a significant scale. The star, 87" north and 18" east of the nucleus of M 33, shows a typical P-Cygni-type spectrum. It varies from about $m_{pg} = 16.5$ to 15.0 ($M_{pg} = -5.5$ to -7.0), and maxima have occurred in 1927-1928, 1934, and 1939-1940.

COLORS OF NEBULAE

Stebbins and Whitford have applied a new photoelectric photometer to the determination of colors of the brighter extragalactic nebulae. The instrument, de-

vised by Whitford, measures through suitable filters the intensities at six spectral regions from $\lambda 3500$ to $\lambda 10000$. The base line for color index is more than three times that of the international scale, and the new device promises a wide application to stars in general. Measures of half a dozen nebulae indicate that these systems are mixtures of stars of different colors. After further calibration on standard stars it is hoped that inferences can be drawn regarding the proportion of stars of different types in various bright nebulae.

LIGHT-CURVES OF SUPERNOVAE

With the use of faint photographic standards established in S.A. 57, Baade has derived definitive light-curves for a number of supernovae. One object, IC 4182 (1937), has been followed through a range of 12 mag. The new curves confirm the provisional results. Supernovae of group I, of which IC 4182 (1937) is the prototype, form a very homogeneous group. The curves become linear about 100 days after maxima, with a mean gradient of 0.0137 ± 0.0012 mag. per day. Light-curves in group II show more or less extended halts on the descending branches and in other respects vary considerably one from another.

ABSOLUTE MAGNITUDES AND RELATIVE FREQUENCIES OF SUPERNOVAE OF GROUPS I AND II

Baade has also derived the following improved values for the absolute photographic magnitudes of supernovae:

Group I: $M_{\max} = -14.05 \pm 0.35$
Group II: $M_{\max} \geq -11.8$ (upper limit)

Although it is difficult to allow for effects of selection, available data suggest that, in average stellar systems, the frequency of supernovae of group II may be six times that of supernovae of group I. Since those

of group II appear from their spectra to be giant analogues of normal novae, the question whether they form a separate physical group needs further investigation.

SPECTRA OF SUPERNOVAE

Spectra of supernovae in NGC 253, 4136, 4559, and 4725 have been observed by Humason and Minkowski. The last of these has a spectrum representing very late stages of group II. The object in NGC 253 is a member of group I, strongly reddened by absorption within the spiral. The objects in NGC 4136 and 4559 are assigned

to group II, although that in 4559 is abnormal in several respects, especially in the very low intensities of the emission bands. Probably for this reason, this object is the first in which the presence of absorption lines has been definitely established. They are clearly seen on two spectrograms obtained by Humason on the relatively large scale of 110 Å/mm at $H\gamma$. According to Minkowski, the lines represent multiple absorption of H and $Ca\text{ II}$. The possibility that this object may represent a third type of supernova or even an unusually bright normal nova cannot be entirely excluded.

LABORATORY INVESTIGATIONS

FURNACE AND ARC SPECTRA

The study of the spectrum of gadolinium by A. S. King has included the completion of wave-length measurements and temperature classification in the region reported on last year, together with extensions into the infrared to $\lambda 10670$, and, by means of a large quartz spectrograph, into the ultraviolet to $\lambda 2135$. A rich spectrum, chiefly of $Gd\text{ I}$ lines, was found in the ultraviolet, and this region, together with the new infrared lines, has been measured.

The spectrum of thulium, one of the rarest elements of the rare-earth group, has been examined from $\lambda 3081$ to $\lambda 8018$ by means of the electric furnace, and temperature classification has been determined for 357 lines, including a segregation of neutral and enhanced lines. The list includes $Tm\text{ I}$ lines in this region from all except the highest levels, as well as the low-level lines of $Tm\text{ II}$. Thulium is regularly found in such close association with erbium that the identification of its lines has been uncertain. The furnace lines were identified by means of unpublished arc wave lengths supplied by Dr. W. F. Meggers. A joint investigation of the erbium spectrum can now be undertaken, since the lines of its companion, thulium, are known. Preliminary

spectrograms have been made for this purpose.

It is of interest that 9 thulium lines, evidently from low levels of the ionized atom, agree closely with faint, unidentified lines in the solar spectrum. Other rare earths have lines of this type in the solar spectrum, and a decision as to the presence of thulium in the sun will be reached when a term analysis of the spectrum is made from the experimental data which are now at hand.

Wave-length measurements of the ultimate line $\lambda 5535$ of barium have been made by A. S. King from the spectra of various laboratory sources. These have been used by Mrs. Sitterly in her comparison with revised sunspot measures to show the probable presence of neutral barium in the sun.

ANALYSIS OF GADOLINIUM I

Dr. Russell is working on the analysis of $Gd\text{ I}$, with the aid of a comprehensive list of lines communicated by King. An analysis of $Eu\text{ II}$ (in collaboration with Dr. Albertson and Miss Davis) is ready for publication. All the strong lines, and most of those of moderate strength, have been classified and numerous terms arising from

the configurations $4f^65d6s$ and $4f^65d^2$ have been found. A great many fainter lines (more than half the whole) remain unclassified. Other atomic configurations should theoretically give rise to an enormous number of lines, and it is probable that the unclassified lines are the strongest members of multiplets which cannot be disentangled without the aid of faint lines not yet observed, despite King's very careful work. In view of the extreme rarity of this element, further progress is likely to be long delayed. All lines of astrophysical importance are already classified.

MEASUREMENTS OF f -VALUES

The program of measurement of the relative f -values of lines of elements of astrophysical interest has been continued by R. B. King. This work has been materially assisted by the use of a Bol high-pressure mercury arc as the source of the continuous spectrum. With this source lines may be observed in absorption at furnace temperatures up to about 3000° C, whereas with a tungsten filament lamp, furnace temperatures giving absorption lines are limited to about 2600° C. Practically all lines of temperature classes III and IV in the spectra of such elements as $Fe\text{ I}$, $Ti\text{ I}$, $V\text{ I}$, and $Ni\text{ I}$ can be observed in absorption. In addition, the low-level enhanced lines of some elements may be brought out in absorption. The relative f -values of 63 lines in 17 multiplets of $Ti\text{ II}$ in the near ultraviolet region have been measured, and work is in progress on the high-level neutral lines of the elements mentioned above.

The measurement of the absolute f -values of 12 lines in 2 multiplets of $Fe\text{ I}$ has been completed. These will serve to place the relative f -values for lines of this element on an absolute scale.

BAND SPECTRA

The collection of photographs of band spectra produced by the arc and electric

furnace has been added to from time to time by R. B. King. The compounds studied have been suggested by various stellar spectroscopists as an aid in the identification of bands appearing in stellar spectra.

PRESSURE EFFECTS

The effects of high vapor densities on the contours of the cadmium lines λ_{2288} and λ_{3261} are being studied by R. B. King and Minkowski. Broadening due to collisions between atoms of the same kind is of particular interest for these lines because, though both lines arise from the ground state of the atom, their f -values differ by a factor of nearly 1000.

A NULL METHOD OF TESTING PARABOLIC MIRRORS

Anderson and Ross have devised a method for testing large mirrors during parabolization which will be applied to the 200-inch mirror, involving the use of the center of curvature instead of the focus. Compared with the usual procedure, in which a plane mirror is employed and the test is made at the focus, the proposed method has, among others, the following advantages: (1) The whole surface of the mirror tested, including its center, is visible throughout the test. (2) The auxiliary optical parts are small, only 10 inches in diameter, and do away with the need for a 120-inch plane mirror for the 200-inch. (3) The adjustments required are very simple and easy to make.

The auxiliary apparatus consists of a simple lens, 10 inches in aperture, designed to have a rather large constant of spherical aberration, and a "corrector," which is a plane parallel plate one surface of which has been deformed very slightly.

The lens is placed on the axis of the 200-inch mirror, approximately 60 inches inside the center of curvature; the monochromatic

light-source is located about 23 inches outside the lens. As the focal length of the lens is more than 23 inches, the image at the conjugate focus is virtual. The lens has been so computed that the virtual image formed by the central zone of the lens coincides with the center of curvature of the mirror, and the image formed by the marginal zone of the lens coincides with the point on the axis where the normals to the marginal zone of the parabolic mirror intersect. The function of the corrector is to insure exact coincidence of the image from any intermediate zone of the lens with the intersection of the normals to the corresponding zone of the mirror.

It is clear that all the light passing through the lens and corrector travels to the mirror surface along its normals and hence will, after reflection, exactly retrace its path to the source if the mirror surface is a perfect paraboloid. Imperfections in the form of the surface will consequently appear in a knife-edge test and the usual interpretations will apply.

RULING MACHINES

Special attention has been given to accidental errors in the small machine which have persisted after the elimination of six possible causes. A seventh, much more difficult to combat, has been corrected through an ingenious technique developed by Prall, in which a 70-pound tool was operated by hand for several weeks. The errors in the plate-carriage ways have now been reduced to about one wave length. Esti-

mates of the resultant gain must await the assembly of the machine.

Rulings have been made chiefly for the purpose of testing the machine, but two 4-inch gratings call for special mention. Intended for use at a dispersion of several hundred angstroms per millimeter, these are unique in having a central hole through the plate. For certain types of spectrographs such gratings have advantages which justify the difficulty of cutting the hole without injury to the grating.

Astigmatism in certain 6-inch gratings ruled on aluminized glass has been traced to nonuniformity in the thick aluminum film required, due to the size of the aluminizing chamber. With new equipment of larger capacity no difficulty is anticipated from this source.

The diamond-cutting machine has been further improved and now gives increased accuracy in the ruling edges. Experiments in reducing the angle included by the faces of the ruling diamond are in progress.

Some valuable additions to the small machine are an automatic stopping device, an improved azimuthal adjustment for the ruling diamond, and a support for the diamond in which springs are used to replace the traditional pivots.

The old machine has been utilized for minor experimental work. A special ruling has been made to determine directly the resolving power of photographic emulsions. Tests at the Research Laboratory of the Eastman Kodak Company have shown its usefulness and the idea is being elaborated.

CONSTRUCTION AND MAINTENANCE

DESIGN AND INSTRUMENT SHOP

Construction of the mounting of the 10-inch photovisual telescope has required about one-third of the time of the instrument shop. The double-cone driving unit

designed by Nichols and many other parts have been completed, and the entire instrument will be assembled and tested in Pasadena this autumn.

Other apparatus which has been de-

signed and constructed wholly or in part during the year includes a new microphotometer, a new Schmidt camera mounting, the monochromator for producing calibration spectra for the coudé spectrograph, a vacuum chamber for aluminum and fluoride films, and improvements and additions to the 2-prism Cassegrain spectrograph.

About 600 hours of the time of the instrument shop have been given to projects relating to national defense.

E. C. Nichols, assisted by H. S. Kinney, has been in charge of design, and Albert McIntire has supervised the work of the instrument shop.

OPTICAL SHOP

In the optical shop Dalton has devoted most of his time to the completion of the figuring of the elements of the 10-inch photovisual lens. Spherical surfaces corresponding accurately to the specifications by Dr. Ross have been finished, and final corrections of zones to reduce spherical aberration are in progress.

During the first part of the year Hendrix was engaged in the preliminary shaping of two 48-inch disks, one of which will form the correcting plate for the large

Schmidt telescope on Palomar Mountain. Since early in 1941 he has given essentially all his time to optical projects relating to national defense.

The Observatory has been actively engaged in two defense projects initiated by the National Defense Research Committee near the beginning of the year. These have required some temporary additions to the technical force and much of the time of one or two members of the scientific staff. Dunham in particular has devoted nearly all his time to these investigations.

BUILDINGS AND GROUNDS

The remodeling of the 60-foot tower telescope on Mount Wilson has been completed and the instrument has been in active operation throughout most of the year. The 10-inch photographic telescope has been dismantled in preparation for the installation of the new photovisual objective and mounting. As in past years, many minor improvements and repairs on Mount Wilson and in Pasadena, including painting, reroofing of several buildings, paving, and construction of retaining walls, have been completed under the superintendence of A. N. Beebe.

THE LIBRARY

During the year the library has added 258 volumes, 53 by purchase, 22 by gift, and 183 by binding, making a total of 14,559 volumes, with about 12,000 pamphlets and 2500 lantern slides. Because of the war little material has been received from

the 200 observatories and research institutions which generally send their publications to the library. For the same reason the number of periodicals received has dropped from a former 140 to 94; of these, 25 are gifts or exchanges.

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SPECIAL PROJECTS: ASTRONOMY

DIRK BROUWER, Yale University Observatory, New Haven, Connecticut. *Program for the determination of systematic corrections to fundamental catalogues from observations of minor planets*

The program of photographic observations of minor planets was undertaken with the purpose of obtaining systematic corrections to the right ascensions and declinations of fundamental star catalogues within a zone of the sky between declinations $+30^\circ$ and -30° .

Observations were commenced in April 1935 at the Yale Station at Johannesburg, South Africa. In September 1935 the Allegheny Observatory began its cooperation in this work, Dr. Keivin Burns, of that observatory, giving the program his most enthusiastic support. Shortly afterward Dr. G. van Herk, of the Leiden Observatory, began a series of observations, first with the meridian circle and later with the 13-inch photographic refractor.

Yale Observatory has undertaken the measurement and reduction of all the plates, with the exception of those secured at Leiden. This work involves the measurement and reduction of between 500 and 600 plates a year. The Observatory also provides the search ephemerides, secures accurate orbits, and will make the final discussion of the observations.

The corrections to the elements of the asteroid orbits and to those of the earth's orbit enter as unknowns of an intermediate nature in the final discussion of the observations. In a ten-year program the number of oppositions of an average minor planet is seven or eight. This number is sufficient for a precise determination of all the orbital elements with the possible exception of the mean motion. In order to strengthen the solutions, it is our intention

to continue the program on a much reduced scale for two or three oppositions beyond 1945. During this additional period only a small number of plates in the neighborhood of the date of opposition will be obtained, just sufficient to secure a single strong normal. Also, it is our plan to collect miscellaneous published observations prior to 1935, as far back as 1924, to furnish a few normals for these earlier years. The latter will have low weight, but, on account of the large coefficient of the correction to the mean motion, they will strengthen the determination of this unknown. The complete plan requires the computation of accurate orbits for the years 1924 to 1948. It should be remarked that the extension of the observing program will not appreciably, or not at all, delay the definitive discussion. It would be impossible in any case to complete the discussion within about two years after the completion of the main observing program in 1945.

The positions of the asteroids are determined photographically in the system of the *Albany General Catalogue*. The orbits are computed by the method of numerical integration, to such a degree of perfection that the final orbits to be used for the definitive discussion can be relied upon to within a few hundredths of a second of arc.

Since the computed positions of the minor planets are entirely independent of the fundamental system of star positions used in obtaining the observed positions, the final discussion of the differences between the observations and the computed

positions affords an independent determination of the systematic corrections to the fundamental system in which the positions are measured.

The most direct method of observation, namely, the measurement on a short-focus plate of asteroid and *General Catalogue* stars, had to be rejected for two reasons: first, the great difference in magnitude between the G.C. stars and some of the asteroids on the program; second, the large probable errors of individual G.C. star positions if brought up to the present time.

Instead it was decided to use the A.G. stars as intermediate stars. For these stars recent photographic positions are now available in declinations $+20^\circ$ to $+30^\circ$ and -10° to -20° , obtained at the Yale Observatory. Work on this program is being continued, and it is estimated that recent photographic A.G. positions for all declinations between the limits -30° and $+30^\circ$ will be available in 1946, practically at the end of the regular observing program of the asteroids. On account of the large number of stars that are common to the A.G. and G.C., the systematic reduction of the positions of the A.G. stars to the system of the G.C. can be obtained with a high degree of accuracy.

With a telescope powerful enough to show the faintest asteroid, a direct measurement of the asteroid with respect to the A.G. stars is the most satisfactory method. This procedure is followed at Leiden.

A more complicated procedure is followed at Johannesburg and at Allegheny and New Haven. On account of their small field, plates taken with the long-focus telescopes at Johannesburg and at Allegheny show, as a rule, fewer than three A.G. stars. The 5-inch Ross cameras at Johannesburg and at New Haven are not fast enough to show the fainter asteroids. By a combination of a long-focus telescope

and a short-focus camera satisfactory results are obtained.

At Johannesburg the Ross camera is mounted on the tube of the long-focus telescope. There the field plate, i.e., the plate taken with the short-focus camera, is secured simultaneously with the long-focus plate on which the asteroid shows. At New Haven are obtained the field plates required for the reduction of the long-focus plates secured at the Allegheny Observatory. Many of these plates are taken afterward, sometimes a year after the date of the Allegheny plates for which they are to serve. In all cases the hour angle at Allegheny and at New Haven is the same within narrow limits.

The procedure is then to measure on the long-focus plate the asteroid and a minimum of three, but usually four, faint comparison stars of approximately eleventh magnitude. These stars are just bright enough to show good measurable images on the field plate. They are measured on the field plate, together with five or six A.G. stars.

A theoretical discussion of the accuracy to be expected shows that the position of an asteroid obtained from a combination of long-focus plate and field plate should have a probable error of about $0\rlap{.}^{\prime\prime}13$, and that measured on a camera plate directly a probable error of about $0\rlap{.}^{\prime\prime}17$.

During the twelve months July 1, 1940 to June 30, 1941, the routine work for the program has been continued without interruption. Excellent progress has been made in the numerical integrations of the orbits with the machines of the Thomas J. Watson Astronomical Computing Bureau at Columbia. First integrations are now available for ten planets for the years 1930 to 1948. The first phase of the work for the extension of these computations backward to 1924 has been completed, and the integrations will soon be undertaken.

For these ten planets a first comparison with observations can now be made for the purpose of obtaining an improved orbit. This second orbit will in practically all cases be the definitive one that will be used for the final discussion of the observations.

During the past year extensive discussions have been made of the observations of two minor planets, (1) Ceres and (7) Iris. These discussions have proved the general correctness of the estimated probable errors referred to earlier in this report. More abundant material will soon be available for a more reliable evaluation of the accuracy of the observations.

S. A. MITCHELL, University of Virginia, Charlottesville, Virginia. *Astronomical studies at the Leander McCormick Observatory.* (For previous reports see Year Books Nos. 38 and 39.)

The 10-inch Cooke camera, the gift of the Carnegie Corporation, has provided a most useful supplement to the 26-inch visual refractor. The 10-inch has been utilized for two different studies: (1) the determination of photovisual magnitudes, and (2) the accumulation of spectroscopic material by means of an objective prism. In the latter project, plates have been secured covering more than half the sky available from this latitude. In addition to these plates taken at the "G" focus, an area of 10,000 square degrees, or one-third of the total available sky, has been covered with the prismatic camera set at the "K" focus. The latter plates are required for stars of early-type spectra; the plates taken at the "G" focus are used for the classification of the stars of later types. The McCormick spectra, thus obtained, can be classified for stars, on the average, down to the twelfth photographic magnitude.

The primary purpose of these spectra is to furnish spectral classifications for the stars included in various McCormick proper-motion programs, described in pre-

At an astronomical conference on "The Fundamental Properties of the Galactic System," held on May 2 and 3, 1941, under the auspices of the New York Academy of Sciences, Dr. Brouwer presented a paper entitled "The reference system with a view to planetary dynamics." This paper (see bibliography below) contains a detailed presentation of the essential features of the asteroid program.

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vious reports. But before extensive investigations are carried through to completion, it is important to know the relation of the McCormick system of classification (see A. N. Vyssotsky, *Astrophysical Journal*, vol. 93, pp. 425-441, 1941) to other standard systems such as those of Harvard, Mount Wilson, Bergedorf, etc.

A very important region of the sky is that within a radius of 10° from the North Pole. For the stars in this region there have been derived in the past ten years, at the Mount Wilson Observatory, the very reliable series of magnitudes and colors which will serve as standards of comparison for all other regions of the sky. Obviously, spectra of these stars in the north polar cap would be a most valuable adjunct to the magnitudes and colors. Twelve of the necessary sixteen plates required to cover the polar cap have already been secured at the McCormick Observatory.

A by-product of special interest is the detection of dwarf M stars. These are easily distinguishable from M giants on McCormick plates and may be picked up

in a visual survey. A systematic survey of 2500 square degrees of the sky yielded twenty-eight M dwarfs, of which only seven were already known. One of the new dwarfs was of the relatively rare type which shows bright hydrogen lines. Heretofore, the discovery of M dwarfs has been confined almost entirely to the stars of large proper motion, and consequently few conclusions could be drawn as to the general character of the motions of stars of this type. The new M dwarfs picked up from the McCormick spectral plates will help to settle questions concerning the space distribution and motions of these stars. Naturally, it is desirable to confirm the dwarf character of these stars by independent

evidence. This may be done by reobserving each star with an instrument of higher dispersion, or by deriving the trigonometric parallax.

Various requests for spectra have been received from other observatories. To date about 300 spectra have been supplied to W. J. Luyten for faint stars of large proper motion. Also D. A. MacRae, a graduate student of the Harvard Observatory, was at McCormick for two weeks in January 1941, during which time he classified over 1000 faint spectra to supplement his researches at Harvard on Milky Way structure. Other research workers in the same subject have made similar arrangements to obtain McCormick spectra.

GEOPHYSICAL LABORATORY

Washington, District of Columbia

L. H. ADAMS, *Director*

Further progress has been made during the year toward an understanding of the way in which the outer layers of our globe were formed. Essentially, the Earth's crust is a complex layer composed almost entirely of rocks which are assemblages of various silicate minerals. To the geologist endeavoring to interpret the structure and past history of the crust, the manner of formation of these rocks directly or indirectly from an original magma is of fundamental interest. It is now recognized that a reasonably complete knowledge of the conditions under which rocks melt or magmas solidify requires a vast amount of systematic measurement of the fusion relations of silicate mixtures. Investigations along this line have occupied a leading place in the program of the Laboratory throughout its existence.

For the most part these particular measurements have gone forward steadily without any very striking events to accent the successive stages of the work. But occasionally a well marked milepost is reached. The past year has witnessed the successful completion, in form for preliminary publication, of the system lime—alumina—ferrous oxide—silica. This represents the first four-component system of rock-forming oxides to be published, and brings experimental petrology into still closer touch with the complex facts of igneous geology.

Another definite advance has been in connection with the study of silicate minerals in the presence of water at high temperatures such as prevail within the Earth. Many experimental difficulties have finally been overcome. The apparatus,

which is essentially an electric furnace within a strong closed chamber in which materials can be exposed to the action of steam at pressures of several thousand pounds and at temperatures far above a red heat, has produced a variety of new and significant results. Precise melting curves with various combinations of silicates and water are being obtained, and as a by-product of these investigations a number of interesting observations have been made. In the course of certain experiments the formation of clear quartz crystals at a fairly rapid rate was observed. Other arrangements of the apparatus caused an unusual deposit of minerals formed by a solution of material in the vapor phase, followed by deposition in another part of the furnace. One of these minerals was sillimanite, which formed long needles of good size, and which has not previously been obtained artificially. It is probable that the manner of its formation in nature is similar in some respects to that observed here. The result furnishes striking evidence of the solution of solids in highly compressed vapor and indicates that deposition from a vapor phase may be an important factor in silicate mineral formation.

The measurement of the radioactive elements in the cores, several feet long, previously collected from the ocean bottom has now reached the stage where it is possible to establish a correlation between radium content and the depth below the upper surface of the sediments. For all the cores except one (which is readily explainable), the existence of a maximum on the curves showing the relation between

radium content and depth, and the consequent important connection of ionium with these curves, establish a time scale. One use of such a time scale is to calculate the rate of deposition of the ocean-bottom sediments. It turns out that the rate may be as little as 1 centimeter per 1000 years for the oozes and even less than this

amount for the red clays. These rates are in substantial agreement with inferences that have been drawn from the extensive lithological and biological studies of the same cores.

The following is an outline of recent and current investigations at the Geophysical Laboratory.

FUSION RELATIONS IN SILICATE MIXTURES (ANHYDROUS)

THREE-COMPONENT SYSTEMS

Substantial progress has been made in the difficult system kaliophilite—nepheline—silica. Experiments were initiated in 1929, and a preliminary report was published in 1935. During the past year eight quenching furnaces were used continuously on long runs on compositions in this system. Liquidus data are complete. A considerable amount of data has been obtained on three-phase boundaries necessary for determining the compositions of the ternary hexagonal solid solutions (nephelines) and the feldspars. At least two or three more years will be necessary to complete this system.

The system nepheline—diopside—silica (which is not ternary) has been further investigated by preparing five new compositions intermediate between jadeite and diopside for use in connection with studies of natural jade.

We expect to initiate some measurements on $\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ at subliquidus temperatures in sealed tubes, and to begin some experiments designed to obtain further data on the variations in chemical composition and optical properties of minerals of the melilite group. It may be possible, by lowering the viscosity of the melts by the addition of FeO as a component, to get more evidence on the behavior of akermanite below about 1325°C , where it breaks down into other

solid phases. Much time has been devoted to preparing for publication the data for several systems the experimental work on which has been completed.

A comprehensive revision of the ternary system $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ has been made. In 1915 the Laboratory published a comprehensive report on this system, the outcome of eight years of work. It was the first three-component silicate system to be investigated, and the results proved to be of value to students of rocks and of ceramic materials. In addition, the results were especially applicable to the cement industry, which is concerned with a small area within the ternary diagram. In the course of this study methods of attack on complex silicate mixtures were devised, and placed on a routine basis. The method of quenching for the determination of melting temperatures and of the location of boundary curves and quintuple points was developed and found to be practicable. The usefulness of the thermoelement of platinum and platinum-rhodium for such work was demonstrated, and its readings were related to the gas-thermometer temperature scale determined at the Laboratory. The measurement of the optical properties of small crystals, only 0.01 millimeter in diameter, with the petrographic microscope was made possible through refinement of existing methods and development of new methods.

In the ensuing years these devices and methods have been improved and developed further. The original experimental data of the 1915 paper have been supplemented by further measurements in connection with various silicate studies at the Geophysical Laboratory, and additional and improved information has been obtained on certain parts of the system. In the revised paper, the manuscript of which is now ready for the printer, this information is included; the text figures have been revised and redrawn; and the physical-chemical relations in this important silicate system have been brought up to date.

FOUR-COMPONENT SYSTEMS

The lengthy investigation of the quaternary system $\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ has gone forward satisfactorily. Experiments on parts of this system were started in September 1938, and a progress report on the investigation was presented a year ago. Since that time, a few more compositions in the $\text{Ca}_2\text{SiO}_4-\text{CaSiO}_3$ -akermanite plane along the line Ca_2SiO_4 have been checked. These new data give a more accurate determination of the reaction point and eutectic and have been included in the revised paper on the system $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$. The system pseudowollastonite (αCaSiO_3)-akermanite ($\text{Ca}_2\text{MgSi}_2\text{O}_7$)- gehlenite ($\text{Ca}_2\text{Al}_2\text{SiO}_7$), a ternary system within the quaternary system, has been completed and published. It combines simple members of the groups of rock-forming minerals, the melilites and the pyroxenoids.

Complete liquidus data for this ternary subsystem are given in the paper, the equilibrium diagram with isotherms is presented, and some new measurements are given for the binary system. Data that locate the three-phase boundaries and conjugation lines (which determine the compositions of solid solutions and the courses

of crystallization of typical ternary liquids both with perfect equilibrium and with perfect fractionation) were obtained and are presented with the aid of diagrams. With perfect fractionation, all ternary liquids yield a final solid solution that approximates 41 per cent $\text{Ca}_2\text{MgSi}_2\text{O}_7$, 59 per cent $\text{Ca}_2\text{Al}_2\text{SiO}_7$. It is shown that zoned solid solution crystals having one or more reversals in the direction of zoning (oscillatory zoning) may be produced by normal processes of crystallization with continuously decreasing temperature.

Theoretical considerations bearing on the courses of crystallization in a system of this type are developed and former theories are criticized. The relation of these results to the composition of melilites occurring in igneous rocks is also discussed.

The problem of the stability relations of akermanite is still unsolved, but work on it is continuing.

The plan of attack on the quaternary system $\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ has been to investigate important planes cutting through the interior of the tetrahedron (considering the quaternary system as an equilateral tetrahedron with each apex a component). The system CaSiO_3 -diopside-anorthite is such a plane and was originally investigated by Koch (1930). His work, however, is seriously in error, and it has therefore been necessary to reinvestigate the system. A total of 81 mixtures has been studied to date. The data on these mixtures are now complete and the manuscript will soon be ready for publication. The anomalous behavior of mixtures containing a small amount of anorthite has slowed up the investigation. Apparently the aluminum ion enters the diopside structure to a small extent, and the CaSiO_3 structure to a lesser extent. This phenomenon, however, does not significantly affect the ternary phase data.

Twenty-eight compositions have been

prepared as a first step in the study of the system diopside—forsterite—anorthite, which is another (not completely ternary) plane through the tetrahedron $\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$.

Work on the four-component system $\text{CaO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ has now been written up for preliminary publication, which will make the information obtained available to the metallurgical, ceramic, glass, and refractories industries. Data will be presented on five planes through the regular tetrahedron used to represent

the quaternary system: (1) FeO —anorthite—silica (52 separate compositions studied); (2) anorthite— Al_2O_3 — FeO (21 separate compositions studied); (3) CaSiO_3 —anorthite— FeO (85 separate compositions studied); (4) gehlenite—anorthite— FeO (35 separate compositions studied); (5) gehlenite— CaSiO_3 — FeO (26 separate compositions studied). These data show which mineral combinations coexist at various temperatures and indicate the approximate locations and temperatures of the important quaternary invariant points.

SYSTEMS WITH WATER UNDER PRESSURE

HIGH-PRESSURE STEAM-QUENCHING APPARATUS

For this work a second bomb, essentially similar to the original one, has been constructed and in operation for several months. A new type of furnace was designed to fit within the bomb as a self-contained unit, and it was thought that it would allow us to dispense with the platinum baffles used in the bomb first built. This did not prove to be the case; the new bomb at 3000 pounds pressure had too great a temperature fluctuation and the hot spot was too high in the furnace. It was used for many runs, however, and has now been rebuilt with platinum baffles. The number of baffles is less than in the first furnace built, but the temperature fluctuation is less and the shift of hot spot with increase in temperature is greatly improved.

The violent fluctuations of temperature and the large shift of the hot spot with pressure in the first form of the new furnace were doubtless caused by too much convective circulation of steam. This led to some interesting observations. For most of its life this furnace was at a high temperature, 1000° or a little lower. The an-

nular space between the furnace tube and the four-holed refractory tube which carried the thermocouple and quenching leads rapidly became filled with silica deposited from the vapor. This deposit was zoned, from quartz in the lower part to amorphous silica in the upper part. It was the cementing together of the inner and outer tubes by this deposit of silica which led to the failure of the furnace.

Lower down, in the hot part of the furnace, other minerals were deposited. As stated in the introductory section, one of these was sillimanite. Other minerals deposited out of the vapor phase are corundum and rutile. The constituents of these minerals come from the refractory tube on which the furnace is wound and from the refractory which is used as heat insulation in the furnace; and the material is dissolved from them by the highly compressed water vapor, then transported from them through the furnace and deposited from the vapor.

Some additional experiments have been made to complete the 3000-pound isobar in the system $\text{H}_2\text{O}-\text{Na}_2\text{O}-\text{SiO}_2$, but no runs at higher pressure have been made. It is evident that the P-T curve of the

binary system $H_2O-Na_2Si_2O_5$ has not yet begun to fall off for the maximum, and it was thought to be of interest to see if the ascending part of the curve, at lower temperatures, could be realized. Runs made at 400° and at 380° and 3000 pounds gave only crystals; hence it is evident that the solubility of sodium disilicate at these temperatures must be very small.

The 3000-pound isobar in the system $H_2O-Na_2Si_2O_5$ -albite is complete except for the melts containing respectively 90 and 100 per cent albite. Preliminary runs have been made which bracket these points, and only the final runs are lacking. The lowering of the liquidus by steam at 3000 pounds is approximately 160° in the composition range from sodium disilicate to the eutectic, and then decreases uniformly as the albite content is increased. Indications are that it will be about 25° for pure albite.

EXPERIMENTS WITH CLOSED BOMBS

Several problems have been studied in small closed bombs in which materials are heated with water, and the bomb and contents quenched by cooling with water. In some of these experiments we have had the new pump set up to assure a known and constant pressure. This apparatus remains tight at 15,000 pounds per square inch, and the photoelectric regulator holds pressure constant to ± 25 pounds.

The solubility of quartz and amorphous silica has been roughly determined at 400° and at 500° in pure water and in mixtures of water and carbon dioxide. At these temperatures above the critical temperature of water, the solubility continues to increase steadily with increasing temperature, and there is no indication of a break at the critical temperature. Amorphous silica gives reproducible values for solubility; these values are greater than those for quartz, as is to be expected, since

the amorphous "solid" phase is unstable with respect to quartz.

Solubilities in the system $Na_2SiO_3-SiO_2$ have been determined for several mixtures ranging in composition from Na_2SiO_3 to 75 per cent SiO_2 at 350° , and some runs have been made at 400° and a number at 500° . The most noteworthy features of the 350° isotherm are (1) the small solubility and (2) the spreading of the field of silica almost over to the disilicate ratio.

The solubility of sodium silicates in water has been determined by others at low temperatures, up to about 85° . Here anhydrous Na_2SiO_3 becomes solid phase, and the solution contains more than 50 per cent Na_2SiO_3 . At 350° the solubility has decreased to 0.7 g in 100 g H_2O . At the lower temperature disilicate has never been crystallized, but the solubility must be large. At 350° , 1.2 parts dissolve in 100 parts water. This retrograde solubility is in sharp contrast to the uniform increase in solubility with temperature in the system $H_2O-K_2O-SiO_2$.

The spreading out of the field of silica as the temperature is lowered seems to be a usual behavior. The binary eutectic (anhydrous) between sodium disilicate (66 per cent SiO_2) and quartz is at 73.5 per cent SiO_2 . At 350° , quartz is primary phase at 68 per cent SiO_2 , sodium disilicate at 67 per cent SiO_2 . It will be interesting to see if at lower temperatures, with solubility increasing, the sodium disilicate field expands at the expense of the quartz. This appears not improbable.

In some of the solubility experiments quartz crystals up to 1 mm in length were formed. Some of these were used as seed crystals in other experiments with water and amorphous silica, and with water and sodium silicate glasses. At $500-550^\circ$ and 15,000 pounds pressure the quartz crystals grew about 0.01 mm per day with amorphous silica. With one of the sodium sili-

cate glasses a growth of 0.37 mm per day was obtained. The crystals grown by transport of silica through the vapor at 15,000 pounds were the better in form.

THE SYSTEM $\text{Na}_2\text{O}-\text{B}_2\text{O}_3-\text{SiO}_2$

In last year's report it was stated that this system was complete except for two areas, and it was proposed to abandon these. Further experiments in the low-temperature area in the interior of the diagram have not succeeded; the liquidus of these mixtures is below the temperature at which the powdered glass will sinter compactly, and it probably will not be possible to do anything more with them. This is unfortunate, because several of the invariant points in the diagram lie within this area. Better success has attended experiments near the side $\text{B}_2\text{O}_3-\text{SiO}_2$.

Melts containing 5 per cent Na_2O are not difficult to make. At this Na_2O content the fields of $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ and quartz adjoin, and the boundary is near 34 per cent SiO_2 and 660° . From the shape of the boundary it would be expected that the quartz field in the binary system would extend to about 30–35 per cent SiO_2 . However, the field of $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ cannot extend to the side $\text{B}_2\text{O}_3-\text{SiO}_2$; hence there must be an invariant point $\text{B}_2\text{O}_3 + \text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3 + \text{quartz} + \text{liquid}$ somewhere in this region. It must be below the melting point of B_2O_3 , hence below 450° . Attempts have been made to get information on this point, but without success. The field of $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ extends to within 1.5 per cent of the side (Na_2O , 0.014; B_2O_3 , 0.731; SiO_2 , 0.255, $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ at 656°). Mixtures nearer the side, and nearer the boundary, have proved puzzling and time-consuming. There is some reason to believe that there may be separation into two immiscible liquids below about 650° . This study is being continued.

THE SYSTEM $\text{NaOH}-\text{Na}_2\text{CO}_3-\text{H}_2\text{O}$

This system, for which solubility determinations at 30° intervals from 60 to 300° were reported last year, has been investigated further in the neighborhood of 300° by means of cooling curves. The melting point of sodium hydroxide has been determined as $318 \pm 1^\circ$, in agreement with the value of $318.4 \pm 0.2^\circ$ reported by Pickering.

The temperature of an enantiotropic transition of sodium hydroxide, to which Pickering had assigned a value of $299.6 \pm 0.5^\circ$, has been found to be decreased by the presence of water. If a melt contains more Na_2O than corresponds to the formula NaOH , the transition takes place at a fixed temperature, namely $293 \pm 1^\circ$; but if a melt contains less than this amount of Na_2O (i.e., contains excess H_2O), the transition takes place at a lower temperature, depending on the amount of excess H_2O . The rate of lowering becomes less as the amount of water increases: thus 0.3 per cent H_2O lowers the transition temperature 2° , whereas 0.9 per cent H_2O lowers it only twice this amount. This behavior is considered evidence that α - NaOH , the high-temperature form, takes H_2O into solid solution, but that β - NaOH does not. It has been found that this solid solution is not affected by the presence of carbonate; for the transition temperatures of melts containing from 0.5 to 10 per cent Na_2CO_3 depend solely on the amount of excess H_2O present.

The liquidus temperature in the binary system $\text{NaOH}-\text{H}_2\text{O}$ at the transition has been estimated by extrapolation to be at 287° and 74.8 per cent Na_2O . This represents the upper limit of the solubility curve of β - NaOH , which was reported last year. The complete results for the field of NaOH in the system $\text{NaOH}-\text{Na}_2\text{CO}_3-\text{H}_2\text{O}$ are now being prepared for publication.

Corrosion of the silver-lined autoclave

by highly concentrated solutions of sodium hydroxide at temperatures up to 300° had been observed to be surprisingly small. For example, a solution contained less than 3 ppm. of silver after it had been heated at 300° in the autoclave containing a gold bottom for a period of 20 hours, during almost half of which time it was being stirred. Some additional experiments, in which NaOH was fused in a silver crucible under different conditions, have shown that silver is attacked to only a very slight extent by fused NaOH in the absence of air; and that the attack is

even less in the presence of gold in contact with the silver. Thus in comparable experiments, in each of which NaOH was fused at 350° for two hours, the melt contained 240 ppm. of silver when the crucible had been exposed to the air, but only 14 ppm. when air was excluded.

The high-pressure steam filter autoclave, the initial construction of which was referred to last year, was completed during the year. It is to be used first for the determination of solubility isotherms at temperatures less than 500° in the system $\text{Na}_2\text{O}-\text{SiO}_2-\text{H}_2\text{O}$.

PROPERTIES OF SOLUTIONS UNDER HIGH PRESSURE

FURTHER EXPERIMENTAL WORK ON P—V—T RELATIONS IN SOLUTIONS

In order to clear up some matters concerning the effect of the nature of the dissolved electrolyte on the P—V—T relations of aqueous solutions, measurements have been made on the expansions of KBr— H_2O mixtures from 25 to 95°, and also of KBr—glycol and CsBr—glycol mixtures over the same temperature range. The compressions of these two last-named series were measured at 25°. A series of determinations of the volumes and expansion coefficients of $\text{NaNO}_3-\text{H}_2\text{O}$, $\text{KBrO}_3-\text{H}_2\text{O}$, and $\text{NaBrO}_3-\text{H}_2\text{O}$ solutions was made at 10° intervals from 25 to 95°. These results, which have not yet been published, were obtained for the purpose of examining the effects of large cations on the expansion coefficient of water.

EFFECT OF PRESSURE ON ACID-BASE EQUILIBRIA IN WATER SOLUTIONS

A knowledge of the effect of pressure on acid-base equilibrium in water solutions is needed as a basis for studies of solutions

in the depths of oceans or in subterranean regions. Previous approaches to this problem have been either theoretical or based on conductivity methods. In order to check previous conclusions and carry out some direct determinations on sea water, the use of an indicator method for determining the effect of pressure on different buffer solutions has been explored. Preliminary experiments were carried out by taking photographs of the absorption spectra of different indicators in buffer solutions under pressure, and analyzing the microphotometer curves of these photographs. The results indicated considerable effects of pressure on the indicator buffer systems. This led to the installation of a photoelectric cell and auxiliary equipment by which the intensity of monochromatic light of wave length close to that of the absorption maximum of the indicator could be measured with adequate precision. A number of borate, phosphate, carbonate, and ammonia buffers have been examined with cresol red and brom phenol blue as indicators. The results are in agreement with the conclusions of previous investigators, except for the carbonate solutions, and indicate that the method is

practicable. By examining the indicators in unbuffered solutions a start has been made in determining an important auxiliary quantity, namely, the effect of pressure on the dissociation constant of the indi-

cator. This work is in progress and, when completed, will lead to definite figures for the effect of pressure on the dissociation constants of the weak acids and bases that have been studied.

STABILITY RELATIONS OF COPPER-IRON SULFIDES

Work has been continued on the melting relations of these sulfides, and on the transformations which take place at temperatures above 600°. The method used has chiefly been thermal analysis; the quenching method has been used for the transformations.

To avoid oxidation and loss of sulfur it has been necessary to enclose the charges in specially designed silica containers. The sulfur-rich mattes have at their melting temperatures a sulfur vapor pressure which is higher than these vessels can stand. Work has therefore so far been confined to the line Cu₂S—FeS and the adjoining part of the ternary system with up to 5 per cent extra sulfur.

No line across this part of the system between the copper sulfide side and the iron sulfide side represents a binary system. The only compounds found at the melting temperatures are chalcocite and pyrrhotite. Extensive solid solution takes place between these two. The melting relations give no indication of the formation of any of the several copper-iron sulfides which in previous investigations at the Laboratory were found to be stable at lower temperatures in mattes of a composition within the field here investigated. A heat effect at 870–900° indicates the formation at this temperature of a compound with a copper to iron ratio of 3:4; possibly Cu₃Fe₄S₆.

The heating curves for mattes with a composition corresponding to the formula FeS indicate that melting takes place over a temperature interval from about 1065

to 1170°. The melting relations along a part of the line Fe—FeS₂ were therefore followed. The mattes with 61.5 per cent iron melt sharply at a maximum melting temperature of 1191°. Mattes with more or less iron than this melt at lower temperatures and over a temperature interval as if they were solid solutions. The composition of the material with the highest melting point corresponds to the formula FeS_{1.090} or Fe₁₁S₁₂, that is, ordinary pyrrhotite. This result may have a bearing on the stability relations of the mineral. Preliminary quenchings indicate a high melting point of pyrite under high sulfur vapor pressure.

The equilibrium conditions of the several sulfoantimonites of silver found in nature are only imperfectly known, and would be of interest, among other reasons because they may afford a usable geologic thermometer in the temperature interval up to 450°. Some work has been carried out by thermal analysis on the system silver sulfide—antimony trisulfide for mixtures with less than 80 per cent silver sulfide. The fusion relations indicate a binary system with formation of the compounds Ag₂S·Sb₂S₃ (miargyrite) and 3Ag₂S·Sb₂S₃ (pyrargyrite or pyrostilpnite). There is no maximum in the melting-point curve at the composition 5Ag₂S·Sb₂S₃ (stephanite), but certain peculiarities in the shape of this curve and of the heating curves indicate that this part of the system is not truly binary. Miargyrite has a transformation point at about 374°.

SULFIDE-LIKE COMPOUNDS

The investigation of the system gold—silver—tellurium has been carried forward satisfactorily. Two papers dealing with parts of the investigation have been prepared for publication, one on the melting point of tellurium, the other on the phase relations in the system silver—tellurium, and a progress report on the above-named ternary system was presented before a local scientific society.

Studies in the field of sulfide-like compounds raise a number of questions as to the stability and formation of chemical compounds and of their natural counterparts, the minerals, which serve to emphasize questions already raised in work with salts, oxide compounds, and metals. Hitherto, the selection of systems for experimental study has often been governed by the importance of the substances from the economic geological point of view, although a considerable amount of scattered work has been done on various isolated systems for other reasons. There has been, however, no comprehensive program of research for applying modern chemical principles to the study of various sulfide-type compounds occurring as natural minerals.

The vast array of sulfide-type *minerals*, which embraces those metal compounds of sulfur, selenium, tellurium, antimony, arsenic, and bismuth which are not hydrolyzed by aqueous solutions, presents, from the chemical point of view, certain regularities which we may note down as follows:

(a) Most of the compounds are of semi-metallic nature, and hence, mixed types of binding may be expected to prevail. The principal compounds appear to be those which would be expected on the basis of the electrostatic type of valency, and the periodicities of properties are in general in

accord with the Mendeleev periodic classification of elements.

(b) The volume relations between the constituent “building blocks” give rise to a number of examples of unusual valency relationships. Thus, to give an isolated example, Ag and S, and Ag with Se form only the normal compounds Ag_2S and Ag_2Se , whereas in the system of Ag and Te, with the large tellurium atom, we find not only the normal compound Ag_2Te , but also a compound which is anomalous from the point of view of simple valency considerations, namely, Ag_5Te_3 . In the corresponding series of copper compounds these relations are less clear because of the two principal valencies of copper itself, namely, uniform and divalent Cu.

(c) “Order-disorder” phenomena play a more prominent part in these compounds than had been suspected from our acquaintance with the subject in other, less metallic compounds. This type of phenomenon plays a very prominent role in metallic systems, the most famous example, now classic, being the system gold—copper. The phenomenon is not unknown in ordinary inorganic chemistry, and familiar examples are Fe_{1-x}O , Fe_{1-x}S , and the ultramarines. Thermodynamically, these are solid solution phenomena, but a closer view requires a knowledge of the structures. The occurrence of unusual and, if one prefers, unpredictable solid solutions is well illustrated again by the series of silver compounds of sulfur, selenium, and tellurium. By ordinary considerations we should expect no “isomorphism” between silver on the one hand, and sulfur, selenium, and tellurium on the other. However, as disclosed in the work on the system silver—tellurium, the temperature of the polymorphic transition in Ag_2Te (and likewise

in Ag_5Te_3) depends on whether silver or tellurium is present in excess. The transition in Ag_2Te saturated with Ag is readily reversible, and occurs at 146° C on heating, 143° C on cooling. On the other hand, when Te is in excess the transition temperature falls; with less than 65.7 atomic per cent, the transition proceeds on heating as low as 122° C , and no reversal takes place on cooling until the temperature falls to below 80° C .

It was of interest to investigate the corresponding transition in Ag_2S (acanthite-argentite). The result was that Ag_2S containing enough excess Ag to extrude hair silver was found to invert on heating at 176.5° C , on cooling at 175.4° C , mean 176.0° C , whereas Ag_2S with excess S inverted on heating at 178.5° C , on cooling at 176.7° C , mean 177.6° C . The difference between the two means is small but real and reproducible. The silver sulfide used in these experiments was the same synthetic lot made up so as to have a small excess of Ag, and the two differed only in that sulfur was added to a portion so as to have a definite excess present. Both preparations were given identical treat-

ments, and were thoroughly annealed before the measurements of the transition temperatures were attempted. Similar measurements were made on silver selenide, Ag_2Se (naumannite). The results in this case are less clear cut, since the transition is much more sluggish than that in Ag_2S . Silver-rich Ag_2Se inverted on heating at 129.0° C (beginning), but on cooling it undercooled to 120.5° and the temperature then rose to 123.1° C . The mean is 126° C . Selenium-rich Ag_2Se began to invert on heating at 132.0° C , and on cooling it undercooled to 124.0° , the temperature finally rising to 124.6° C . The mean is 128.3° C . Since both the means are within the region of indifference, it is impossible at present to state with certainty whether there is a real change in the transition temperature in this compound. A different method of evaluating the transition temperature will have to be applied to settle the question.

Other examples of unorthodox behavior of the sulfide-type compounds are already known, as for instance in the iron sulfides. Much work remains to be done in this field along the lines sketched out above.

CRYSTAL STRUCTURE BY X-RAY ANALYSIS

A structural examination of the mineral bornite (Cu_5FeS_4) has been started, a previous study of this mineral by de Jong having left some points open to question. A great difficulty in structural work on bornite has been to secure a single crystal for X-ray analysis. Crystals of bornite from Illogan, Cornwall, have been kindly supplied for the present investigation by Professor M. A. Peacock, of the University of Toronto. This specimen, although it does not have crystals with faces sufficiently good to yield signals on the reflection goniometer, nevertheless yielded a fragment of a single crystal that has been suc-

cessfully adjusted by X-rays preparatory to making a set of equi-inclination Weissenberg photographs. It is hoped that these Weissenberg photographs will make it possible to clear up the uncertainties concerning the structure.

During the past year a considerable amount of time has been devoted to the setting up of a new X-ray outfit assembled from parts obtained from the General Electric Company and the General Electric X-ray Corporation, together with some parts made in the Laboratory's shop. The central feature of this outfit is an X-ray tube of the Coolidge type recently devel-

oped by the General Electric X-ray Corporation (the CA-4 X-ray diffraction tube), having a copper target and Linde-mann-type windows. The new General

Electric tube gives a beam of more accurately controllable intensity than is possible with the ion-type tube with which most of our work has been carried out.

RADIUM CONTENT OF OCEAN-BOTTOM SEDIMENTS

As mentioned in the introductory section, the determination of radium in cores previously collected from the ocean bottom in various localities has furnished a means of ascertaining the rates at which the sediments were deposited. It was noticed that the shape of the curves of radium concentration against depth resembled curves obtained from a sum of exponential terms and applicable to radioactive systems not in equilibrium. Since it was obvious that uranium and ionium must play an important part in connection with these curves, a method of measuring uranium was developed. The ionium content could be calculated from a special feature of the curves, namely a maximum radium content at a depth below the surface of the sediment depending on the rate of deposition. This maximum radium content must occur after a definite lapse of time following depo-

sition. The mathematical problem is the solution of an equation containing the sum of three exponential terms and two parameters. The characteristics of the equation were studied, and the radium data were analyzed with the aid of this equation and its derivatives, so as to calculate the various rates of deposition in terms of centimeters per 1000 years, correction being made for the distortion of the cores during sampling. These results are in agreement with many of the inferences of Bradley and his associates in connection with their studies of the lithology and biology of the North Atlantic cores.

The expectations with regard to obtaining additional cores from even greater depths were not fulfilled, because of mechanical difficulty due to spreading of the drum flanges of the portable winch on the voyage from Boston to the Nares Deep.

EFFECT OF PRESSURE ON THE CURIE TEMPERATURE

The study of the effect of pressure on the Curie temperature was continued during the past year, and the difficulties experienced with the pressure apparatus above 6000 atmospheres were finally overcome. A cooling device permitting thermostatic control of temperatures down to 0° C has been installed.

The rise in the Curie temperature (reported last year) in the cadmium ferrite, magnesium ferrite preparation (solid solution, spinel type) under pressure up to 6000 atmospheres, measured by the change of its permeability with temperature at this pressure as compared with that under

atmospheric pressure, was confirmed. With the same preparation, measurements were made under a pressure of 12,000 atmospheres, and a rise of 6° in the Curie temperature was found to take place. This indicates, therefore, an approximately linear relation between pressure and rise of the Curie temperature.

At lower temperature an intersection of the permeability curves with and without pressure is indicated. The meaning of this is not clear, and as the permeability measurements seem to approach steady values only very slowly, some unmixing or inversion in the solid solution preparation may

be taking place. A substance of simpler composition is needed to clarify this point. This would be generally desirable for these experiments, and for this reason it is thought that metallic gadolinium would present the most suitable material. Through the kindness of Dr. Wickers, of the National Bureau of Standards, gadolinium bromate was obtained from which it is hoped to prepare the metal. Greater difficulties than were anticipated have been

encountered in accomplishing this work. Chief among the difficulties is that of devising a sufficiently resistant container for carrying out the operations that are required to reduce and concentrate the metal. As each unsuccessful attempt makes it necessary to gather and purify the gadolinium, much time is taken up by this work, but there is good reason to expect that sufficient gadolinium of the requisite purity will be obtained.

PETROFABRIC ANALYSIS

A study was made of some of the gold-quartz veins of Grass Valley, California, with financial support from the Geological Society of America. Collection of oriented specimens in the field and study of the asymmetric zoning of the quartz crystals, and of asymmetric coatings on the specimens, made it possible to determine the direction of motion of the solutions in the veins. In each case studied, this direction was approximately parallel to the rake of the ore shoot. In the smaller veins the quartz fabric is a growth arrangement with the c-axes of the quartz standing almost normal to the vein walls. A similar fabric was found in drag folds along faults, which indicates that probably the quartz came in after the drag folding. This has been a controversial question, but the fabric evidence appears to solve it.

The solubility experiments with silica, referred to above, indicate that the solutions were probably dilute and could not have held up inclusions of country rock. These "unsupported" inclusions can be explained by several generations of quartz.

During the summer of 1940 the gold district at Jardine, Montana, was also visited with Dr. George Seager, of the School of Mines at Butte, who has mapped and studied the area. An unsolved problem was the relation of mineralization to

regional metamorphism. Fabric studies have shown that the mineralization is later than the metamorphism that produced the schistosity but is probably related to a younger and less intense metamorphism that folded the schist locally.

A contact garnet that shows iridescence both on crystal faces and in thin section, and anomalous birefringence, was sent by Dr. J. D. Barksdale, of the University of Washington. The birefringence shows up as parallel lamellae, which the universal stage shows to be parallel to (110) and (111). They resemble polysynthetic twinning. The iridescence appears in zones parallel to the trace of the (110) planes and is probably due to minute inclusions along these planes, whether they are twinning composition planes or not. Heating a thin section of the garnet at 1060° C for 48 hours produced practically no change. At 1185° the birefringence was very weak, but its pattern was unchanged. At 1225° much of the garnet broke up into spinel and pseudowollastonite, but the general pattern and iridescence were unchanged. In the part that remained clear the (111) and (110) planes were readily visible, but the birefringence was extremely weak. At 1250° the whole section melted to a brown glass.

If the iridescence is due to fine twin-

ning, then the two phenomena should decrease and disappear together. If, however, it is due to minute inclusions parallel to a composition plane, the inclusions might maintain their position and cause iridescence even when the birefringence and "twinning" had been partially destroyed by heating. Along some of the (110) planes there are discolorations that

could be minute inclusions, but the highest power available on the microscope failed to resolve individual particles.

On a recent trip to the Adirondack Mountains garnets of another composition were collected for further melting experiments. It is hoped that work with garnet may be continued, with synthesis of the mineral in view.

GRAVITY MEASUREMENTS

The new model of the gravity meter has been given extended field tests and found to be quite satisfactory. Many gravity stations have been occupied repeatedly with it, and at each station the values of gravity obtained at different times have agreed within 1 milligal. The total time required to occupy a gravity station is from 15 to 30 minutes. The instrument is carried in a covered truck and the measurements are made inside the truck. During transport the instrument rests on a platform supported on the inflated inner tube of a motor-car tire. To make an observation the instrument (total weight, 100 pounds) is lifted by a pulley off the platform and moved along an overhead track toward the rear end of the truck to the upper plate of a rigid tripod which extends through the floor of the truck and is lowered to the ground, where it rests on steel plates on small sandbags. The instrument is lowered to the tripod plate, accurately leveled, and made ready for the gravity measurement. The actual measurement requires 4 or 6 minutes, depending on the adopted schedule of operations. Successive readings are carefully timed and the time schedule is adhered to strictly. After the measurements have been made, the boom of the spring is returned to its vertical hanging position; the spring is lifted by supporting pans so that it is not under load. During transport the slight strains intro-

duced during the measurements at a station are given time to dissipate, so that at each station the same undeformed measuring device is used; there is no deformation of the spring between stations, and the need for checking back on a station to ascertain the drift due to deformation is obviated.

At each station the temperature and air pressure within the instrument are recorded; the elevation of the station is checked by barometric readings; the terrain in the immediate vicinity (100 yards) is sketched and described. The air pressure within the instrument is held constant at 8 mm of mercury. Over a period of 9 months no detectable departure from this pressure was observed. The temperature inside the instrument is held constant at 39.2° C by an electrically operated thermostat. The thermostatic arrangement is of the cascade type and utilizes a special bimetal strip with relays to control the heating units. Although the bimetal strip is less sensitive than a mercury control element, it is rugged and practicable for field work. It has been in continuous operation for a period of 9 months. By its use the temperature is maintained constant within $\pm 0.15^{\circ}$ C. The temperature within the instrument is read from two special mercury thermometers to 0.00° C and a small temperature correction is applied to the observed readings. Experience has shown

that this method of thermostatic control is satisfactory. The temperature correction is 7.6" of arc for a change of 0.01° C in temperature. When the thermostat control is obtained through use of ice, the temperature inside the instrument is maintained constant to within $\pm 0.01^{\circ}$ C.

Work on a program of closely spaced stations from the eastern part of the Allegheny Mountains eastward through Maryland, the District of Columbia, and Vir-

ginia to the coast has been in progress for some months, and many gravity stations within this region have already been occupied. Nearly all the gravity pendulum stations of the U. S. Coast and Geodetic Survey in this area have been occupied both with the improved gravity meter and with its predecessor. Several other field expeditions with the instrument have been planned, but they are to be held in abeyance during the present emergency.

VOLCANOLOGICAL STUDIES

A considerable amount of time has been devoted to correlating the samples collected on the various expeditions to the volcanoes of Central America. This preliminary work has made it possible to decide what methods to use for the more detailed investigations. Special attention is being given to the alteration of the igneous rocks by the "acid" steam. A suite of such rocks has been examined microscopically (in thin sections) and chemically. The alteration is surprisingly extensive, and other than calcium in the form of anhydrite very little is left of the bases originally present in the rock. The bulk of the material is opal and anhydrite. The studies include also a number of analyses of the unaltered igneous rocks. It is hoped that the results will be ready for publication by the end of this year. Study of this alteration is important because much of the Santiaguito dome is involved in the attack of the acid gases.

Attention has been directed to the analysis of the acid waters obtained when the

fumarolic steam is condensed. The preliminary investigations show that a lower concentration of sulfuric acid is found in the new so-called sulfur area mentioned in the report for last year, as compared with the condensates obtained from sulfur-free fumaroles. On the other hand, sulfur dioxide and hydrogen sulfide are present in greater amount in the former than in the latter. Hydrochloric acid and much lower concentrations of hydrofluoric acid are present in both. It was also found that hydriodic acid in easily recognizable concentrations is present in the condensates from both fumarolic areas.

Attention is also being given to the concentration of various elements in the incrustations and to the analyses of the extruded rocks. This analytical work has the definite end in view of comparing the concentration of the various elements with those found in the rocks; and it will also enable us to correlate the petrographic data with the bulk analysis of the unaltered rocks.

COOPERATIVE STUDIES

Investigations in which the Laboratory has cooperated in one way or another with various institutions and individuals in-

clude the following: measurement of the thermal properties of solutions, under the direction of Professor Frank T. Gucker,

of Northwestern University; measurement of the heats of dilution of very dilute solutions, under the direction of Professor Alexander Silverman and Professor A. L. Robinson, of the University of Pittsburgh; investigation by spectroscopic means of the distribution of the chemical elements occurring in rocks and minerals and their disposition during geological processes, under the direction of Professor W. H. Newhouse, of the Massachusetts Institute of Technology; determination of radium in sea water, in cooperation with Dr. Elisabeth Rona and with the Marine Biological Laboratory; measurement of the radioactive content of ultrabasic rocks, in cooperation with Dr. H. H. Hess, of Princeton

University; study of the foraminifera in ocean-bottom cores from the Bartlett Deep, the Cayman Trough, and other places, by Dr. Joseph A. Cushman; study of mineral relations in natural jade, in cooperation with Dr. A. V. Kidder, of the Institution's Division of Historical Research; computation of Fourier series for crystal structure analysis, in cooperation with Professor A. L. Patterson, of Bryn Mawr College; and measurement of heat flow in natural rocks, by Dr. A. E. Benfield, of Williams College. It is to be regretted that progress in some of these lines of work has been delayed because of the press of duties connected with the present national emergency.

ACTIVITIES IN CONNECTION WITH NATIONAL DEFENSE

A number of assignments emanating from the Army and Navy have been undertaken by the Laboratory. Eleven members of the scientific staff have been engaged, either full time or part time, on matters relating to scientific aspects of national-defense problems. The Director of the Laboratory has been made chairman of a Section in the National Defense Research Committee. This Section is respon-

sible for a comprehensive program of fundamental importance. The necessary researches involve problems in physical chemistry for which by experience and special apparatus the Laboratory is well equipped. In addition to the staff members now engaged on this program, other members will be brought in as rapidly as the various lines of attack can be resolved into separate experimental procedures.

SUMMARY OF PUBLISHED WORK

- (1034) Physical tendencies. George W. Morey. Symposium on "Glass: What is old? What is new?" (Amer. Chem. Soc.). Ind. and Eng. Chem., vol. 32, pp. 1423-1427 (1940).

Physical trends in glass today include the production of essentially new materials of greatly increased strength by controlled heat treatment, of new compositions (also as the result of controlled heat treatment), and of new applications of glass in fields to which its properties make it especially adaptable. These new uses include architectural panels, glass building block, and the several new in-

dustries built on glass fiber. The control and enhancement of physical properties make possible these new uses and applications of glass.

- (1035) Radioactivity of ocean sediments. III: Radioactive relations in ocean water and bottom sediment. C. S. Piggot and Wm. D. Urry. Amer. Jour. Sci., vol. 239, pp. 81-91 (1941).

Since its beginning the ocean has been the repository of materials removed from the continents. All but radioactive atoms have a continuous existence and may go into and out of the ocean many times. Because radio-

active substances change with time their presence in the ocean is transitory and of peculiar interest.

There is much less radium in the ocean water and much more in the bottom sediment than is appropriate to the uranium present in each place. Studies of core samples of deep ocean sediments several meters long reveal that some mechanism exists which removes radium, and its immediate parent ionium, from the water and leaves most of the uranium behind. The ionium produces more radium, and the excess of these two elements, unsupported by uranium, eventually disappears, leaving an equilibrium based on the small uranium content, which is of the same order of magnitude as is found in ordinary sedimentary rocks. It is now apparent that the high radium content of the ocean sediments is transitory and of no great geo-physical significance. Several mechanisms for this separation and concentration are discussed.

- (1036) Notation for the derivatives of the two types of line integral in thermodynamics.
G. Tunell. Jour. Chem. Phys., vol. 9, pp. 191-192 (1941).

Work and heat are defined in thermodynamics as line integrals that depend on the path (i.e., the entire series of states through which the body or system passes); standard mathematical symbols adequate for the purposes of thermodynamics are available for such line integrals, but the same is not true of their derivatives. The derivatives of the work and heat line integrals are total derivatives with respect to the variable chosen as the parameter defining the path of the integral. For example, if the path (of a homogeneous fluid system of constant mass and composition) be defined by the equation $p=f(t)$, the derivative of the work line integral is given by the following equation:

$$\frac{dW}{dT} = p \left(\frac{\partial V}{\partial T} \right)_p + p \left(\frac{\partial V}{\partial p} \right)_T \frac{dp}{dT}.$$

This equation for the derivative of the work line integral holds for any path in the T,p plane (except a straight line parallel to the p

axis). For a path parallel to the T axis in this plane the equation reduces to

$$\frac{dW}{dT} = p \left(\frac{\partial V}{\partial T} \right)_p.$$

Now in thermodynamics many different planes are used (such as the p,V plane, the T,V plane, the E,S plane, the T,S plane, etc.) and a concise but unambiguous notation for the derivatives of the work and heat line integrals along paths parallel to the coordinate axes in each of these planes has been very much needed. In Eucken's *Grundriss der physikalischen Chemie* and in Sherwood and Reed's *Applied mathematics in chemical engineering* the symbol $(dQ/dT)_r$ is used precisely to represent the derivative along a path parallel to the T axis in the T,V plane of the heat line integral, and it seems desirable to urge that the symbol with straight d 's, parentheses, and subscript be accepted generally in this sense. It may be suggested finally that confusion between the new usage (following Eucken, and Sherwood and Reed) of the symbol with straight d 's, parentheses, and subscript, and the old usage (in which this symbol denoted an ordinary partial derivative) is very unlikely, the old usage having been discarded by mathematicians since the time of Jacobi.

- (1037) The radioactive determination of small amounts of uranium. Wm. D. Urry. Amer. Jour. Sci., vol. 239, pp. 191-203 (1941).

In most specimens of geophysical interest any radio-elements present are in equilibrium, and the concentration of uranium has heretofore been calculated from the radium content. Radium measurements are quite reliable and the calculation is unambiguous. In a study of the radioactivity of ocean-bottom deposits and ocean water, it has been found that the elements of the uranium series are not in equilibrium and therefore the uranium concentrations must be measured by a direct method. Such a method is described in this paper. The principle of co-precipitation is employed to separate the uranium from the other radio-elements, and the alpha-particle activity of the uranium is determined as a mea-

sure of its concentration. The method has been tested by determining the ratio of the alpha-particle activity of the uranium to that of the radium in geological specimens older than a million years, where this ratio should be unity. A mean value of 0.98 ± 0.06 for this test establishes the validity of the method. The observational limit is about three parts in ten million parts of sample, which is below the requirements for the present purpose. Methods for lowering the observational limit are suggested.

- (1038) Pressure—volume—temperature relations in solutions. IV: The apparent volumes and thermal expansibilities of sodium chloride and sodium bromide in aqueous solutions between 25 and 95° . R. E. Gibson and O. H. Loeffler. *Jour. Amer. Chem. Soc.*, vol. 63, pp. 443–449 (1941).

This paper gives the first results of the study of the combined effects of large temperature and large pressure changes on solutions of inorganic electrolytes in water. In it experimental measurements of the specific volumes of aqueous solutions of sodium chloride and sodium bromide are described, tabulated, and discussed. The results cover the whole range of concentration and were obtained at 10° intervals from 25 to 95° . The data are presented in the form of equations expressing the specific volume as a function of the temperature and as a function of the concentration. From these equations the thermal expansibilities, the apparent and partial volumes, and the apparent expansibilities were computed at different temperatures and concentrations.

An analysis of the results in terms of the electrostrictive effects of the ions and their effects on molecular distribution in the solution gives an explanation of some interesting features of the results, especially of the maxima in the apparent volume—temperature curves. It suggests that, although the bromide ion has a slightly larger effect in breaking down the water structure than the chloride ion, the main differences between these two ions are attributable to the fact that the radius of the chloride ion is smaller than

that of the bromide ion, and hence its polarizing power is greater.

- (1039) Pressure—volume—temperature relations in solutions. V: The energy—volume coefficients of carbon tetrachloride, water and ethylene glycol. R. E. Gibson and O. H. Loeffler. *Jour. Amer. Chem. Soc.*, vol. 63, pp. 898–906 (1941).

This paper reports experiments designed to compare water with two other liquids in regard to certain thermodynamic properties which are of especial interest in discussions of the effect of pressure and temperature changes on liquids and solutions.

New measurements of the specific volumes at 25° , the thermal expansions, and the compressions have led to the compilation of a table of the volumes at any temperature and pressure in the range 25 to 65° and 1 to 1000 bars for carbon tetrachloride, and in the range 25 to 105° and 1 to 1000 bars for ethylene glycol. A similar table covering the range 25 to 85° and 1 to 1000 bars has been compiled for water, older values of the expansions and new measurements of the compressions being used. The thermal expansibilities, the compressibilities, the pressure—temperature coefficients, the energy—volume coefficients, $(C_P - C_V)$, and other related properties have been computed from these data.

The energy—volume coefficients of carbon tetrachloride decrease slightly with rise of temperature at constant volume. This is regarded as the normal behavior of actual liquids and is explained in terms of the effect of change in molecular distribution on the repulsive component of the energy—volume coefficient. For water, the energy—volume coefficients behave quite differently from those of other liquids, but all the differences may be accounted for by the addition of a term which gives the change with volume in the hydrogen bridge energy of the liquid. The magnitude of the term is reasonable. Qualitatively, the behavior of ethylene glycol resembles that of water, but quantitative considerations indicate that the assumption that distribution changes in glycol and glycol solu-

tions have only a minor effect on the volume properties of these liquids seems to be justified.

The effect of temperature on the energy-volume coefficients of the liquids is correlated with the variation with volume of their specific heats at constant volume. A comparison of the thermal expansibilities of the liquids at constant pressure and at constant volume is also made.

- (1040) Ionization chamber for counting alpha-particles. Wm. D. Urry. Rev. Scientific Instr., vol. 12, pp. 289-290 (1941).

Radioactive problems of geophysics require the measurement of extremely small concentrations of the radio-elements. Some of these concentrations can best be determined by counting the alpha-particles emitted from solid sources. The ionization chamber must be designed with special care when only a few alpha-particles per hour are to be counted. The chamber described in this note has been designed to minimize the time of loading and unloading and thus to reduce the possibility of contamination by the radioactive nuclei prevalent in any laboratory air. For more than a year the limit of observation has been held to $3/n^{\frac{1}{2}}$ alpha-particles per hour, for a measurement of n hours, without recourse to periodic cleaning. The ionization chamber functions satisfactorily with a vacuum-tube electrometer and photographic recording, but is equally adaptable to a linear amplifier and tape recorder. The apparatus has been used to determine the rate of emission of alpha-particles from sources containing the isotopes of uranium, from sources containing the isotopes of thorium, and from radium sources.

- (1041) Heat energy from radioactive sources in the Earth. Wm. D. Urry. Jour. Wash. Acad. Sci., vol. 31, pp. 273-284 (1941).

An important item in the program of the Geophysical Laboratory has been the determination of the heat production by radio-elements in rocks. Having in mind the need for a large number of separate measurements, the Director of the Laboratory at one time or another discussed with various individuals

the feasibility of more rapid and convenient methods for determining the radioactive heat production in representative rocks from all parts of the world. In particular he requested the author to examine the possibility of determining heat production in materials containing small amounts of uranium and thorium, together with their disintegration products, merely by measurements of the rate of alpha-particle emission. The theoretical treatment given in this paper indicates the feasibility of this method and shows how the total rate of production of heat from all the naturally radioactive elements may be determined to within the required degree of accuracy.

The relation of the rate of production of radioactive heat at any time in the past to the rate at present constitutes a corollary to the main purpose of the paper. This problem is treated rigidly and a solution is obtained in terms of two fairly well established independent variables, namely, the thorium to uranium ratio and the potassium to uranium ratio. The paper is concluded with an appendix which indicates that the existence of radio-elements which have so far escaped detection but which might have contributed a considerable quantity of heat to the rocks of pre-Cambrian times (10^9 to 2×10^9 years ago) is unlikely.

- (1042) The melting point of tellurium. F. C. Kracek. Jour. Amer. Chem. Soc., vol. 63, pp. 1989-1990 (1941).

A new measurement of the melting point of tellurium was made because the values reported in the literature are highly discordant and an exact value was needed in the course of an investigation on the ternary system gold-silver-tellurium. The tellurium was purified by vacuum distillation in pyrex glass. It was found that the distilled metal was free of selenium, the principal impurity likely to be present, and melted at $449.8 \pm 0.2^\circ$ C.

- (1043) Physical reflections in a chemical mirror. R. E. Gibson. Jour. Wash. Acad. Sci., vol. 31, pp. 325-348 (1941).

This paper, which was given before the Philosophical Society of Washington as the address of the retiring president, traces the

origin of the main ideas now used in the theories of solutions, shows how the complexity of this subject arises from the number of variables of coordinate importance that are involved, and develops the theme that in a study of the history of the theories of solutions the student may see reflected all the major advances in physics during the past two centuries.

- (1044) The atomic arrangement of sylvanite. George Tunell. Amer. Mineralogist, vol. 26, pp. 457-477 (1941).

The atomic arrangement of sylvanite has been determined in the present investigation by röntgenographic analysis of faceted crystals from Cripple Creek, Colorado, from Săcărâmbu (Nagy-Ág), Transilvania (Siebenbürgen), and from the Buena Mine, Jamestown District, Colorado. The crystals had a metallic luster and steel-gray color; their identity was confirmed by measurement on the two-circle reflection goniometer. New crystallographic axes were chosen for use in the structural investigation to conform with the arrangement of the symmetry elements assumed in the "Internationale Tabellen zur Bestimmung von Kristallstrukturen." The dimensions of the unit cell, all determined by purely röntgenographic measurements, are $a_0 = 8.94 \text{ \AA}$, $b_0 = 4.48 \text{ \AA}$, $c_0 = 14.59 \text{ \AA}$, all $\pm 0.02 \text{ \AA}$, and $\beta = 145^\circ 26' \pm 20'$. The measured density is 8.16; the corresponding X-ray density is 8.17. The unit cell contains 2AuAgTe_4 , and a small part of the silver atoms required by this ideal formula is replaced by gold atoms. The space-group is $C_{2h}^4-P_2/c$. The seven parameters defining the atomic positions were determined by calculation of the intensities of the diffraction spots of Weissenberg equator photographs of crystals rotating about the a -axis and [201] zone-axis; the positions of the atoms were confirmed by a Fourier projection of the structure on the plane 010 made from a Weissenberg equator photograph taken with the crystal rotating about the b -axis. The gold atoms are situated in (a) 000; 00 $\frac{1}{2}$, the silver atoms in (e) $oy\frac{1}{4}$; $oy\frac{3}{4}$, with $y = 0.433$, and the two sets of tellurium atoms in (g) xyz ; $\bar{x}\bar{y}\bar{z}$; $\bar{x}y\frac{1}{2}-z$; $x\bar{y}\frac{1}{2}+z$, with $x_1 = 0.289$, $y_1 = 0.031$, $z_1 = 0.999$, and $x_2 = 0.277$, $y_2 = 0.425$, $z_2 = 0.235$. Each gold atom and each silver atom is surrounded octahedrally by six tellurium atoms, and each tellurium atom is surrounded octahedrally by three tellurium atoms, two gold atoms, and one silver atom, or by three tellurium atoms, two silver atoms, and one gold atom.

- (1045) Apparatus for determination of small quantities of radium. Wm. D. Urry and C. S. Piggot. Amer. Jour. Sci., vol. 239, pp. 633-657 (1941).

The very small amounts of radium encountered in geophysical specimens necessitate special apparatus, of extreme sensitivity, for their determination. Over a period of some sixteen years the equipment for making such determinations has undergone much development both at this Laboratory and elsewhere. The apparatus here described incorporates the best features of previous designs, and it has demonstrated its ability to evaluate 1×10^{-14} gram of radium in an observational period of 20 hours. Its advantages include high precision, elimination of fluxes and chemical manipulation, automatic compensation of extraneous ionization, automatic calibration every hour, and continuous recording over any desired number of hours. The permanent record is made on motion-picture film on which are also recorded all the scales necessary for subsequent calculations. This apparatus has functioned continuously for several periods of three months, and no difficulty has been encountered from the humidity prevailing in the summer months at Washington, D. C. Radium measurements of a variety of solids and liquids have been made which range from 0.003 to 25×10^{-12} gram of radium per gram or cubic centimeter.

- (1046) Pressure—volume—temperature relations in solutions. VI: The apparent and partial volumes of sodium bromide dissolved in glycol and the energy—volume coefficients of the solutions at various pressures and temperatures. R. E. Gibson and

O. H. Loeffler. *Jour. Amer. Chem. Soc.*, vol. 63, pp. 2287-2295 (1941).

This paper extends the use of solutions in ethylene glycol as models in the study of aqueous solutions. It throws light on the curious fact that the apparent volumes of salts dissolved in water increase with rise of temperature both at constant pressure and at constant volume, by showing that the apparent volumes of the same salts dissolved in glycol are independent of temperature at constant volume, and hence attributes the origin of the abnormal behavior of the apparent volumes of salts in aqueous solutions to the molecular distribution in water.

Results are given for a series of solutions of sodium bromide in glycol covering the whole range of concentration, the volumes being determined as functions of pressure, temperature, and concentration between 25 and 105° C and 1 and 1000 bars. From these data the thermal expansibilities, the compressibilities, the pressure-temperature coefficients, the energy-volume coefficients, and ($C_P - C_V$) for the solutions were computed. In addition, the apparent and partial volumes, compressibilities, and thermal expansibilities of sodium bromide in the solutions were calculated. The energy-volume coefficients are approximately independent of concentration in the range of pressure and temperature studied. The thermal expansibilities of ethylene glycol both in the pure state and in solution are representable by a single linear function of a quantity which is obtained directly from the compressibilities of the solutions.

(1047) The ternary system pseudowollastonite—akermanite—gehlenite. E. F. Osborn and J. F. Schairer. *Amer. Jour. Sci.*, vol. 239, pp. 715-763 (1941).

The system pseudowollastonite—akermanite—gehlenite is a ternary system within the important quaternary system $\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$. In this ternary system the maximum number of crystalline phases in equilibrium with liquid is two: an akermanite—gehlenite solid solution (melilite) and pseudowollastonite (αCaSiO_3). There is no ter-

nary eutectic, but a ternary minimum exists at 1302° C at the composition CaSiO_3 51 per cent, $\text{Ca}_2\text{MgSi}_2\text{O}_7$ 20 per cent, and $\text{Ca}_2\text{Al}_2\text{SiO}_7$ 29 per cent.

Complete liquidus data for the ternary system are given and the equilibrium diagram with isotherms is presented. Some new data are given for the binary systems. Data which locate the three-phase boundaries and conjugation lines (which determine the compositions of solid solutions and the courses of crystallization of typical ternary liquids both with perfect equilibrium and with perfect fractionation) were obtained and are presented with the aid of diagrams. With perfect fractionation, all ternary liquids yield a final solid solution which approximates 41 per cent $\text{Ca}_2\text{MgSi}_2\text{O}_7$ (akermanite), 59 per cent $\text{Ca}_2\text{Al}_2\text{SiO}_7$ (gehlenite). It is shown that zoned solid solution crystals having one or more reversals in the direction of zoning (oscillatory zoning) may be produced by normal processes of crystallization with continuously decreasing temperature. Theoretical considerations bearing on the courses of crystallization in a system of this type are developed. The relations of the results to the composition of melilites occurring in igneous rocks is discussed.

(1048) Factors involved in submarine core sampling. C. S. Piggot. *Bull. Geol. Soc. Amer.*, vol. 52, pp. 1513-1523 (1941).

The Geophysical Laboratory has had the good fortune to secure a number of core samples of deep ocean-bottom sediments of more than usual length. These have yielded an astonishing amount of information in many departments of scientific investigation, and it may be assumed that similar samples will continue to be of great value. However, the reliability of the interpretations derived from studies of such samples is dependent on a knowledge of the degree to which these cores represent the original condition of the undisturbed sediment before the sampling apparatus penetrated it. Any studies involving rates of sedimentation are particularly dependent on a quantitative measure of the distortion of the samples. Since such quantitative

comparisons with the sediments lying below miles of sea water are not available directly, studies have been made by obtaining samples of varved glacial clays, operating the apparatus in the usual way, and measuring the distortion in such samples directly in comparison with the varved clays *in situ*. The quantitative relations so established provide corrections which may be applied, with precautionary reservations, to samples of submarine sediments. These corrections have proved to be sufficiently reliable to be of considerable value.

- (1049) Gravity-measurements in Guatemala. F. E. Wright. Trans. Amer. Geophys. Union, 22d annual meeting, pp. 512-515 (1941).

In connection with volcanological studies in Guatemala, especially of the volcano Santa María and its offshoot Santiaguito, by Dr. E. G. Zies, of the Geophysical Laboratory, series of measurements of certain geophysical quantities, such as the vertical component of the Earth's magnetic field, the electrical potential, and Earth resistivity, have been made at various places and important results obtained. Gravity measurements and seismological data have also been suggested as addi-

tional possible aids in this study. As a preliminary to gravity measurements with a gravity meter, a gravity base station was occupied in 1940 at Guatemala City with a pendulum apparatus of the U. S. Coast and Geodetic Survey; also one at Quezaltenango. The measurements yielded the values: $g = 977.985$ (elevation 1494 meters) at the National Meteorological Observatory in Guatemala City; and $g = 977.781$ (elevation 2384 meters) at Quezaltenango. These values are of only a fair degree of accuracy because of a rather large correction for flexure.

In the study of an active volcano, its dynamic aspects are extremely important and should be investigated by repeated occupation, at definite time intervals, of a carefully selected network of stations at which geophysical measurements can be made. Subcrustal changes can then be detected and followed by changes in certain of the measured geophysical quantities. Analysis of these changes over a sufficiently long time period may then enable the volcanologist to obtain information on the behavior of the Earth's crust below the volcano at depths which are otherwise quite inaccessible to him.

- (1050) Annual Report for 1940-1941.

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DEPARTMENT OF TERRESTRIAL MAGNETISM

Washington, District of Columbia

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SUMMARY

The effective investigation of the Earth's magnetism and electricity requires international collaboration since many fundamental researches depend on observations of geomagnetic and geoelectric phenomena from all parts of the world. During the report-year, July 1, 1940 to June 30, 1941, many of the countries from which, in the past, needed data were obtained have been enmeshed in war and thus have had little opportunity for geophysical research or collaboration. Necessarily, therefore, the activities of the Department have been directed to further detailed study of the accumulated material at hand.

In the United States also many specialists were called to develop the scientific aspects of projects concerned with national defense. In conformity with the action of the Trustees, the services of the regular scientific and administrative personnel and use of equipment, site, and buildings have been contributed without cost to the Government. Thus for the year ending June 30, 1941, nearly 20,000 hours and over 5000 hours of the budgeted scientific and administrative personnel, respectively, were diverted from the Department's program of geomagnetic, geoelectric, and nuclear-physics investigations. Four men of the regular staff are also on leave of absence at the Naval Ordnance Laboratory and the Naval Research Laboratory. Seventy-five additional investigators, including physicists, engineers, assistants, and technicians—many through the generous granting of leave from universities and commercial organizations—had been en-

gaged prior to June 30, 1941, to assist in development of urgent projects submitted by the Navy and Army through contracts with governmental agencies.

It is perhaps surprising that so many practical uses of the Department's data, technique, instruments, and experience have been found in this connection, not only in the laboratories at Washington and in the current programs of the Watheroo (Western Australia), Huancayo (Peru), and College (Alaska) observatories, but also in its world-wide operations and accumulated data in the field. The completion, early in October 1940, of the new Cyclotron Building and its almost entire assignment to defense activities added greatly to the space already available.

Despite these demands, it was possible to maintain a skeleton staff in all the sections, so that the regular work was without too serious interruption. Furthermore, it happens that many developments in the national-defense work have possibilities in connection with future investigational work in geomagnetism, and at the end of the present emergency we may look forward to application of these researches to our ordinary activities.

The international character of the emergency has somewhat hampered realization of the resolution, adopted by the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics in 1939 at Washington, that the newly adopted three-hour-range index of geomagnetic activity should replace from 1940 the scheme of numeri-

cal characterization of days. That these indices from the world's magnetic observatories may be available for reference, they are being collected and compiled at the Department and promptly published. The value of this activity in facilitating correlative studies of geomagnetism and cosmic phenomena has been established already (see last year's report and p. 98 of this report).

Geomagnetic investigations. A powerful method for analyzing geomagnetic fields by surface integrals was further developed. This method usefully supplements that of spherical harmonics, which sometimes becomes unwieldy in the case of special types of fields. The data can be represented in terms of functions other than spherical harmonics, or in graphic form. A separation of a magnetic field over any closed regular surface S into parts originating inside and outside S was obtained with the aid of Green's theorem. Surface integrals were also derived permitting the calculation of the potential when its normal derivative is known, or vice versa, when these integrals exist, in the case of spherical and plane surfaces. Conditions under which measurements of a field over a portion of S may permit useful calculations of the field at points elsewhere on S were also considered. In computing the field in terms of surface integrals for harmonic regions of space adjacent to S , use was made of well known solutions of the problems of Dirichlet and Neumann. An application of the method to the field of magnetic storms is in progress.

An investigation of the polar fields of sudden commencements of storms reveals that the geomagnetic north component of a commencement diminishes and the vertical component increases with increasing geomagnetic latitude in the region inside the auroral zone.

Average values of the disturbance diur-

nal variation, the solar daily variation, daily means of disturbance, and noncyclic change for international disturbed and quiet days were reduced for nearly all stations of the Polar Year, 1932-1933. These data are being used in a study of the average characteristics of geomagnetic fields.

New methods of predicting future fluctuations in geophysical phenomena from observed changes in the past are under investigation.

The investigation of the relations of geomagnetic with solar, lunar, and other cosmic phenomena was continued by Bartels, Chapman, and Johnston, and the results reported last year were confirmed and extended.

Further investigation of the magnetic field of the volcanic region of Guatemala was undertaken using the data obtained from over 1100 observations of vertical intensity by the last two years' cooperative expeditions of the Geophysical Laboratory and the Department. Although it is not possible now to define accurately the magnetic field of the volcanic rift from the data at hand, there is evidence that the effects noted are not of extreme local character, but are associated with a general tectonic feature of the entire Central American region. Therefore, it is evident that the survey should be extended over a much wider region than was originally anticipated. These results indicate the desirability of similar field-research in other volcanic regions, for example, around Mount Lassen.

All the measurements on the CIW primary magnetic standard were made and the analyses of the results are nearly complete. They indicate that the required accuracy has been attained, so that the coil-constants can be specified to approximately one part in a million. The actual instrument is not quite finished because of

temporary assignment of personnel to other urgent problems. The standard is ultimately to be installed at the Cheltenham Magnetic Observatory.

Terrestrial electricity. Current investigations of atmospheric-electric phenomena were designed largely to aid in making a better evaluation and in gaining a better understanding of that current of electricity in the atmosphere, the supply-current, whose origin is not definitely determined but which maintains the negative charge of the Earth despite the continuous loss of charge by electrical conduction through the atmosphere. The magnitude of the supply-current and its temporal variations may be estimated from measurements of the vertical electrical conduction-current in the atmosphere. To determine whether a given body of data for the conduction-current is representative for the Earth as a whole is the immediate objective of several investigations now in progress, for example: (a) statistical analyses of conduction-current data for the Watheroo Magnetic Observatory; (b) comparison of these chiefly with similar analyses of corresponding data for the oceans—apparently the most representative thus far obtained; (c) investigation of specific factors on which the electrical conductivity of the air depends and which may accordingly be sources of local or regional characteristics of the conduction-current. These specific factors are: the concentration of the ion-population in the atmosphere; the character of atmospheric ions; the rate at which ions are formed, destroyed, or removed from a given space in the atmosphere; and the part played by certain molecular aggregates—nuclei of condensation—in determining the concentration of that class of ions on which the electrical conductivity of the air chiefly depends. Those results which are amenable to a more abbreviated summarization than

that given in the body of this report are as follows:

The diurnal variation of the electric conduction-current at Watheroo is largely of universal character, but there is evidence of a regional component which may be attributed to a diurnal variation in the total resistance of the vertical column of air over that station; it is surprising to find in the latter no dependence on season. The conduction-current at Watheroo is relatively unaffected by conspicuous smoke from bush-fires, although at these times there is a marked decrease of air-conductivity and a corresponding increase of potential-gradient, indicating that the smoke does not extend high enough to increase appreciably the resistance of the vertical column of air.

Counts of the nuclei of condensation in small samples of air are expected to have a randomness such that the variance, i.e., the square of standard deviation, is equal to the mean for a large number of counts; but a suitable statistical examination of a large body of data showed that the optimum estimate of the variance is definitely less than the mean and that this disparity apparently does not depend appreciably on observer, instrument, or a variety of experimental conditions.

It was shown by experiments that when air is passed through ducts, a fraction of the nuclei of condensation is generally removed, but the less turbulent the air-stream, the smaller is that fraction.

An examination was made to determine whether atmospheric-electric phenomena at the Earth's surface are subject to characteristic disturbances when bright "solar flares" appear accompanied by characteristic disturbances of the Earth's magnetic field, of electric currents in the Earth, and of short-wave radio communication; but none was found.

Ionosphere. Continued observation of

the ionosphere at Huancayo and at Watheroo has now yielded sufficient homogeneous data to permit more detailed systematic analysis of electrification of the outer atmosphere than has ever before been possible. These data are especially valuable for predicting the performance of radio-wave propagation over long distances.

The automatic equipment at the observatories is increasing the store of data for attacking a number of theoretical problems, among which are the systematic changes of ionization of the outer atmosphere associated with geomagnetic storms. Detailed study of the great magnetic storms of March 24, 1940 and March 1, 1941 has led to much clearer ideas of the change in the upper atmosphere during such storms, indicating that definite atmospheric movements may be associated with storms of this type.

The nature of the ionization in the outer atmosphere of polar regions presents a major problem in investigation of the Earth's magnetism and its variation. It is known that electrically charged corpuscles bombarding the Earth's atmosphere are deflected toward the polar regions as they come within the influence of the geomagnetic field. Resultant ionization of the high atmosphere in these regions, where the Earth's field is directed almost vertically with respect to the surface, produces auroras and special conditions of current-flow in the atmosphere which cause violent fluctuations in the magnetic field. Accompanying such disturbances are great variations in the received intensity of long-distance radio transmissions which pass through the polar regions. The relation of these phenomena and the distribution of the ionization in polar regions present a problem the solution of which not only is of theoretical importance but has practical application to problems of radio-wave

propagation. Investigation of the polar ionosphere has been undertaken by the Department through the establishment, in cooperation with the University of Alaska, of an observatory on the University campus in the zone of maximum auroral activity. All known methods of studying the high atmosphere are brought to bear in this investigation, including magnetic, ionospheric, and auroral observations. Acquisition of homogeneous data from this location is of great importance in that they not only are unique, but also enhance the importance of the data from Huancayo and Watheroo. The wide range of latitude permits for the first time analysis of the important and complicated variation of the upper atmospheric electrification with latitude, and provides for more accurate interpretation of conditions of radio-wave propagation. At least two phenomena previously unobserved have become evident but await further study before announcement.

Modulated searchlight apparatus was further developed for measurement of the ozone-content of the lower atmosphere and of the density and temperature of the upper atmosphere. The successful tests with it indicate that this development will allow attainment of the results predicted by theory and by the results of the previous year. The work had to be interrupted by assignment of personnel to national-defense projects. Some measurements were made on the variation of the light from the night sky with the idea of correlating this with ionospheric measurements, but the preliminary results, though interesting, were not extensive enough to permit definite conclusions. As regards the ozone-measurements, both the receivers and the transmitters for the ultraviolet were procured, and the original sources and photocells are already available for the

visible. From a technical point of view, therefore, considerable progress was made.

Nuclear physics. Research in nuclear physics was restricted because many of the staff were assigned for full or part time to problems of national defense. Experimental work has been done, however, on the photodisintegration of deuterium using high-energy gamma rays, and on associated problems, as well as in development work on the Atomic-Physics Observatory. In connection with the photodisintegration of the deuteron, an absolute calibration of the gamma-ray intensity arising from the disintegration of fluorine by protons was made.

The new cyclotron laboratory was completed by contractor R. H. Burrows early in October 1940. The magnet was installed, and most of the accessories are complete or in manufacture in the instrument-shop of the Department. Barring unforeseen difficulties, the cyclotron should be ready for operation early in 1942.

Observatory- and field-work. The observatories at Huancayo and Watheroo continued their extensive programs of geophysical observations. Cooperative work was continued in atmospheric electricity at Apia, in atmospheric electricity and earth-currents at Tucson, and in maintenance of international magnetic standards at the

Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey.

Geomagnetic and auroral results obtained at the observatory, near Little America, of the United States Antarctic Expedition during April 1940 to January 1941 are being reduced and compiled.

Cooperative work with surveys in Africa, Australia, and New Zealand, through loan of CIW instruments, resulted in many secular-variation observations at CIW stations. These mutually profitable cooperative enterprises are being continued and extended through special expeditions or surveys as opportunity permits.

Miscellaneous. Albert Smith, who for twenty-eight years so efficiently served as cabinet-maker and carpenter, was placed on the retired list July 31, 1940, having reached the age of sixty-seven. Because of the emergency and need of added skilled personnel, he again assumed active duty December 2, 1940. The Department was fortunate also in having on active duty from November 1940 magneticians J. W. Green and W. F. Wallis, and from February 1941 C. C. Ennis—all on retired status. The opportunity of having these four men of long experience return to active duty has helped to maintain continuity of parts of the ordinary program which otherwise would have had to be greatly curtailed.

INVESTIGATIONAL AND EXPERIMENTAL WORK TERRESTRIAL MAGNETISM

Those of the staff giving full or part time to geomagnetic investigations were Berkner, Fleming, Forbush, E. A. Johnson, Johnston, Jones, Ledig, McNish, Root, Scott, Torreson, and Vestine. Research Associates Bartels and Chapman gave constructive advice and did research at Berlin and London; Bartels was in residence at Washington until September 23, 1940,

when he left for San Francisco to return to Germany via Japan and Siberia.

PERMANENT FIELD

Physical representation of the geomagnetic field. A general theory of analyzing surface magnetic fields by integrals was extended (Vestine) to give continuations

of the field in adjacent regions of free space. Means were also found for computing the strengths of current in spherical sheets in regions of free space adjacent to surfaces on which the measurements of field are made. The method provides a useful alternative to that of spherical harmonic analysis, for use in the case of fields adequately defined by measurement. It is moreover more general and free from many limitations naturally associated with the method of spherical harmonics, and is applicable to observations made on any regular closed surface. It is hoped that procedures for computation by machine may be developed to facilitate use of the method.

Expressions are derived giving a unique separation of a field observed on a closed surface into parts originating outside and inside the surface. A method of computing a field of internal origin at points outside, or vice versa, is incidentally derived. The special cases of spherical and plane surfaces are also treated. Integrals yielding the potential (apart from a constant) from the vertical force and for obtaining the vertical force from prescribed values of the potential were obtained for fields originating either entirely within or entirely without a closed surface. Analogous expressions give continuations of the field over a surface and to adjacent regions of free space. Numerical applications are being made to geomagnetic fields unsuited to the technique of spherical harmonic analysis. The utility of operational and Fourier methods in field analysis is also being examined.

Reduction of field-data to mean epochs. A simple method for correcting mean daily observations at field-stations to mean of year, on a world-wide scale, was found practicable. This method permits considerable improvement in many estimates of the magnitude of secular change at field-

stations through the use of data for magnetic observatories at considerable distances from the field-station. The problem was attacked by considering the magnetic conditions during the Polar Year, 1932-1933. The monthly mean departures from annual means of magnetic intensity were first considered for many widely distributed observatories. It was found that these departures varied in a systematic way with position over the Earth. The agreement shown between observatories was on the whole surprisingly good, often within 2γ ($1\gamma = 0.00001$ CGS unit), but in a number of cases the agreement shown was surprisingly bad, with discrepancies of over 100γ ; it appears highly probable that the quality of the observations of fluctuations in the field at observatories can be rather rigorously compared on a basis of this kind.

It was found that monthly mean departures from the annual mean, corrected for secular change, depend mainly on geomagnetic latitude and season. The geomagnetic north component is small near the geomagnetic poles, and greatest near the auroral zone. Just outside the auroral zone this component diminishes rapidly with decreasing geomagnetic latitude, and it attains a secondary maximum in magnitude near the equator. The changes found in the geomagnetic east component were comparatively very small in all latitudes. The vertical component is large inside the auroral zone and small in middle latitudes, becoming very nearly zero near the equator, but the fluctuations in this component are badly determined.

Mean daily departures in the field from monthly mean values showed characteristics similar in general type to those of the symmetrical part of the disturbance field of storms, and indicated the presence of important post-perturbation effects. Application of the results of 12 field-observations

in South America gave a correction of daily mean to mean of year as high as 50γ in horizontal intensity, H . It was found that the necessary correction for mean of day to mean of year can be made using data for only a few carefully selected observatories. In all cases the corrections for these equatorial observations were negligible in declination, D , and appeared to be small but ill defined in inclination.

The investigation of methods of correcting magnetic observations to mean of day is in progress. It was found that these corrections in low and middle latitudes are in general likely to be smaller than are those involved in correcting for post-perturbation to mean of year, in the case of H , but are more important in the case of D . In high latitudes the corrections to mean of day are large owing to the large amplitude of the solar disturbance daily variation S_D .

Mathematical treatment of geomagnetic charts. Chapman prepared a connected group of five papers on isomagnetic charts. They give a theoretical discussion of the singular points on such charts, and of the nature of the isomagnetic lines; an exact mathematical treatment then follows of the isogonic and X - and Y -charts for the centered dipole field; the fourth and fifth papers deal with the occurrence of dipoles and with the form of the various isomagnetic lines in their neighborhood. A sixth paper is to be the first of a further group of three, and deals with the determination of the earth-air current from the isomagnetic charts for the declination, D , and the horizontal intensity, H , or, alternatively, assuming that this current is negligible, it provides a means of checking the mutual consistency of the D - and H -charts. These theoretical discussions indicate possible improvements in the construction of future isomagnetic charts.

Geomagnetism and volcanic structure.

During the Guatemalan Expedition of 1939-1940, observations were confined largely to extension of the magnetic profiles obtained by the survey of 1938-1939 across the rift, and to the establishment of new profiles to ascertain if the effects observed in the immediate vicinity of the volcano Santa María were also encountered at other parts of the rift. Analysis of the data (McNish) confirms this speculation. The very low values of vertical intensity occurring at the volcanic rift were located at other points along the rift. On the Pacific and the inland sides of the rift, a decrease of the magnetic vertical intensity with latitude was observed which closely resembles the ordinary decrease in this element with magnetic latitude. However, a definite offset in the continuity of this decrease occurs at the rift. Thus, as one proceeds from an inland point toward the volcanic rift, vertical intensity is found to be decreasing at a slightly greater rate than might be expected from the pure latitude-effect.

On the other side of the rift this slope is of similar magnitude, but if one were to extrapolate the magnetic field from one region into the other, using the average rate of change over both regions, a definite offset in the actual field as compared with the extrapolated field would be noted. That is to say, the normal vertical magnetic field observed on the Pacific coast is something like 1000γ ($1\gamma = 0.00001$ CGS unit), or more, greater than one would expect it to be from the observations on the inland side of the volcanic rift.

Some curiosity is aroused as to whether or not this offset is a characteristic of the entire western mountain range of the American continents. Thus the question arises, to what extent the magnetic field is due to activity at the rift or to a major tectonic feature which, in turn, is responsible for the existence of the volcanic rift.

The solution of these problems must await the acquisition of further data, but those already obtained indicate clearly the importance of magnetic surveys to an understanding or at least an apprehension of the general geological structure located at great depths beneath the surface rocks.

COSMIC RELATIONS

Geomagnetic studies on fluctuations in solar and lunar daily variations. More elaborate treatment for determining the solar, S , and lunar, L , daily variations was evolved and discussed (Bartels and Johnston) in a second paper on geomagnetic tides in horizontal intensity at Huancayo. A new viewpoint was found which seemed likely to lead to better methods than those used hitherto in the computation of L for the main term $L(M_2)$ arising from the partial tide M_2 and also the subsidiary terms depending on lunar distance. This led to a "principle of efficient sampling in geophysical statistics," a general expression for ideas underlying previous work. This principle, when applied to present methods of computing L , reveals the main reason for the rather unsatisfactory results of former computations on L . These results showed irregularities indicating the presence of large residuals due to nonlunar influences, both "regular" (such as that due to the average value of the solar daily variations S)—believed to be eliminated—and "irregular" (such as that due to disturbance of the variability of S)—believed to be sufficiently "overwhelmed" by combining a great number of observations. L is mainly given by the semimonthly waves in the hourly means; these must be determined piecemeal from successions of undisturbed days. A different order of magnitude of S in each fragment obviously introduces error in the result obtained for L ; this becomes clear in the

change of the average if a few days or groups of days are omitted. For $L(N_2)$, the main distance-term, this error is worse, because it is derived from still smaller fragments, namely, groups of days centered at perigee, apogee, etc. A remedy could be found by a more elaborate treatment, determining S and L from each fragment separately by least-square methods. In practice, however, it is more convenient to abstract L from the *changes in the diurnal variations from one day to the next*.

The further essentials of this long second paper may be briefly summarized by the titles of the various sections, as follows: application to the computation of L ; calculation of group-sums for twofold changes; final computation of $L(M_2)$; calculation of $L(M_2)$ for determining the suppression of L at night; the effect of lunar distance on the tide-producing forces; the partial tides expressing the effect of lunar distance; the prospects of determining geomagnetic effects of lunar distance; partial tides relative to main tide; preliminary results on distance-effects based on daily ranges; specimen computation of $L(N_2)$ illustrating the successive computation of matrices; new formula for $L(M_2)$ and its discussion; relation of the new method to that of Chapman and Miller. This investigation was continued by Bartels after his return to Berlin in November 1940, and it is hoped his work since then may be further reported next year.

The computations on the lunar daily variations in magnetic and meteorological data, done at London under Chapman's direction, were continued, though somewhat less intensively since the outbreak of war, and a report on some of the results is in progress. Chapman completed a paper on the statistics of magnetic disturbance at Greenwich during 62 years, which is a by-product of an investigation of

the lunar daily variation of horizontal magnetic intensity, H , at Greenwich; publication awaits opportunity to put in final form the many diagrams required.

MAGNETIC DISTURBANCES

The further cooperation between Chapman and Ferraro has led to the publication of a paper dealing with the first phase of a geomagnetic storm, during which, for a few hours, the horizontal magnetic force over the major part of the Earth is raised above its normal value. The change is due mainly to an external magnetic field superposed on the normal field, but the growth of this external magnetic field induces electric currents within the Earth whose magnetic field nearly cancels the vertical component of the external field and enhances the horizontal component. About two-thirds of the latter is due to the external field, which appears to be nearly uniform over the space occupied by the Earth; its direction is approximately northward, parallel to the Earth's magnetic axis, and its intensity may be taken, in illustrative calculations, as 20γ for a moderate magnetic storm.

In the original account of their theory of geomagnetic storms, Chapman and Ferraro discussed the mode of formation of a hypothetical ring-current, to which the main phase is attributed; also its size, density, current-intensity, and rate of decay. That discussion was supplemented by a series of notes, in the first of which, already published, the existence of the ring is assumed and its radial stability is considered.

Some progress was made in an investigation of magnetic bays of the Polar Year, 1932-1933 (Vestine, Silsbee). As in the case of bays examined by others for low latitudes, bays in polar regions appear most frequently near the equinoxes. It was also noted that there is little variation in

average frequency with time of day, but a marked dependence of amplitude and sign on local geomagnetic time. Near and north of the auroral zone negative bays appear with marked maximum in amplitude near local geomagnetic midnight, and greatly outnumber the positive bays, which tend to be more marked about 7 hours earlier. South of the auroral zone positive bays occur more frequently. There is also a clearly defined 27-day recurrence-tendency in bays. At Thule, near the center of the auroral zone, the horizontal disturbance force of bays yields an annual mean vector rotating in a clockwise sense with time of day. On consecutive days there sometimes appear overhead surges of current in polar regions showing fields of remarkably similar pattern.

Using a method devised by Chapman, current-systems are being derived for the field of several sudden commencements of the Polar Year, 1932-1933 (Vestine, Silsbee), assuming these to flow in the atmosphere. In high latitudes the vertical disturbance force was found to increase with increasing geomagnetic latitude, and the north component becomes relatively very small near the geomagnetic north pole.

Good progress (Vestine, Lange) is being made in the reduction of the seasonal variations in the disturbance daily variation and noncyclic change for international days for stations of the Polar Year, 1932-1933.

An investigation (Berkner, Seaton) of ionospheric changes associated with the magnetic storm of March 24, 1940 was completed (see p. 81).

The magnetograms for the great magnetic storm of March 1, 1941 have yielded data for further analyses, particularly as the recent installation of wide-range equipment at a number of observatories made complete details available. Thus the records at Niemegk, reported by Bartels,

show the following ranges: D , $4^{\circ} 26'$; H , 2115 γ ; Z , 1687 γ . The sum of the ranges in the three elements was 5219 γ , an all-time record of actual recording.

Cosmic-ray investigations. Acting for the Institution's Committee on Coordination of Cosmic-Ray Investigations, considerable attention (Forbush, Lange, Fleming) was given to maintenance of the CIW precision cosmic-ray meters at five observatories, and to compilation and discussion of resulting data. Notable progress, improvement of technique, and discovery, both cosmic and geophysical, were made in this field as described in the report of the Committee (pp. 117-135).

ARCHIVES OF MAGNETIC RECORDS

The archives of magnetic records acquired during the Second International Polar Year were maintained at the Department. Owing to the troubled international situation no records were added to this collection. The collection which is available, however, was used in connection with regular researches of the Department and proved valuable in supplying desired information on problems associated with national defense.

The photographic method of Peters and Green for reducing magnetograms of different stations to common time and ordinate scales was modified and considerably simplified (Vestine). The modified device also permits the use of microfilm for copying in case a high degree of accuracy is unnecessary.

Chapman's preparation of "Notes on isomagnetic charts" led him to investigations on Halley's charts, and he has written a historical article on them which will appear, with a number of reproductions of isogonic charts, in a future issue of the *Occasional Notes* of the Royal Astronomical Society.

UPPER ATMOSPHERE

The experimental investigation of the upper atmosphere was continued (1) with the 30-inch equipment developed last year and (2) with the 60-inch searchlights kindly loaned by the War Department (Aronson, E. A. Johnson, Murphy). Work since June 1940 has had two principal objectives, namely, (1) measurement of the shift in the so-called ozone-ceiling, and (2) measurements of variation with time of total night-sky light and qualitatively of any variation in its spectral composition.

The general plan of last year for measuring light scattered from a modulated searchlight beam was modified and improved. Ozone is evidenced by its absorption of light in the wave-length region 2200 to 3000 Ångström units. Therefore, comparison of the scattered light in this region with scattered light coming from a near-by wave-length region, say 3000 to 4000 Ångströms at different altitudes, will indicate the presence of ozone at any altitude by a sharp decrease in the light scattered by the lower wave-lengths. The modulation which "tags" the beam for identification by the tuned amplifier-receiver was limited to the ultraviolet by using glass rather than metal modulator-vanes, and the modulator was materially reduced in size. The sensitivity of the photocells to ultraviolet light was increased by using special cells in quartz envelopes and by coating the entrance window of glass-enveloped cells with a powder which, when subjected to radiation of 2500 Ångströms, fluoresces light of the wave-length region of 4000 Ångströms.

Measurement of variations of total night-sky light, made without a searchlight, gives merely the direct-current value of the sky-light subtended in the 1°5-field of the receiving mirror. The limiting of the

field of view makes this method important, as most previous methods take in a large unknown area of sky.

Pending design and construction of proper fittings for the two 60-inch rhodium reflectors, the work was begun with smaller mirrors. The small transmitter, made of a $31\frac{1}{2}$ -inch aluminized reflector, uses as a source one water-cooled 1000-watt high-pressure mercury arc in a quartz jacket with a self-contained pumping system with radiator. The modulator is made up of pyrex glass (spectral transmission and low thermal expansion-coefficient) in order to modulate only the ultraviolet. Improvements in the small receiver of last year include a 7-inch elliptical mirror (to decrease the obliquity of the light incident on the photocell), which was designed, ground, and polished at the Department. This permits use of filters in the beam and reduces light-losses. To simplify placing of the photocell-holder, a hole was drilled through the back of the parabolic mirror and the final focus of the ellipse was located there. Two light-tight holders, necessary to accommodate the varied shapes of the photocells, were designed and constructed to hold the photocells and electrometer-tubes; these may be used in either the small or the large receiver.

The new receiver consists of a 60-inch parabolic rhodium mirror and a 20-inch aluminized elliptical mirror. The new transmitter, partially completed, consists of a 60-inch rhodium mirror at the focus of which will be three 1000-watt high-pressure mercury arcs run from three-phase alternating current and mounted in a special quartz jacket. The mount to hold this jacket and the new pyrex modulator are in construction in the Department's shop. A new low-noise, high-gain amplifier is in construction. It incorporates inverse feed-back to insure maximum sta-

bility, which is essential when working near the limit of measurement.

Tests were made on the noise arising in the amplifier, in the electrometer-tube pickup, and in the photocell, and good resistance-noise curves were obtained. The spectral sensitivity of photocells and spectral transmissions and reflectivities of parts of the searchlight-system were tested. It was found that two reflections from rhodium mirrors will give about 70 per cent of the signal given by two reflections from aluminum.

Tests on the sensitivity of glass-jacketed cells to the ultraviolet when used with fluorescent powder show that in the region of 2300 to 2800 Ångströms the sensitivity of such a glass cell is increased by at least a factor of 8, but this does not bring its sensitivity up to that of a quartz-jacketed cell. Higher output at short wave-lengths was obtained when the arc ran alternating current slightly under its rated voltage.

Runs for color of the night-sky showed a variation of ± 4 per cent in the total radiation, but it is impossible to say whether this variation was caused by actual sky-radiation or variations in the lower atmosphere. Variations of color were noted, but again the cause was undetermined.

Using the searchlight itself with the small transmitter and the small receiver with a Cs-O cell in quartz, with complete modulation, a signal of 0.5×10^{-13} amp was detected at an altitude of 16 km. With ultraviolet modulation only, a signal was picked up to 8 km. Using the small transmitter but the large receiver and the same photocell, full modulation gave a signal of 2.49×10^{-13} amp at 21.6 km. Using ultraviolet modulation, the signal was 1.41×10^{-13} amp at 10.7 km. Measurements at wave-lengths above and below the ozone absorption-band were made by placing a suitable filter in the receiver. Up to 9 km the total ultraviolet signal was 2.06×10^{-13}

amp, and the ultraviolet signal below the ozone absorption-band, as calculated from the reading with filter in, was about 0.6×10^{-13} amp.

INSTRUMENTAL DEVELOPMENTS

Electromagnetic method. All the measurements at temperatures 20° C and 28° C on the coil of the primary electromagnetic standard were made by Wallis and J. W. Green, and analyses of the results were partly completed pending the report of the National Bureau of Standards on the Department's stainless-steel length-standard. The preliminary results show that the coil-constants can be specified to approximately one part in a million. No appreciable variations in pitch or diameter were found. The mechanical design of the standard was completed and the instrument is now nearly finished. There remains to be done the installation of the coil in the support and the installation of the entire equipment at Cheltenham.

Wide-range magnetograph. Because of the installation of a wide-range magnetograph under more favorable conditions at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey, the wide-range equipment installed during April 1940 in the Standardizing Magnetic Observatory was disassembled for use elsewhere.

New magnetometer design. Experimental work done (McNish) on a device for measuring the Earth's magnetism, the sensitive element of which is completely free from vibrational and dynamic effects, indicates that it may be extremely useful for rapid and accurate magnetic surveys. Further development was postponed because of diversion of personnel and shop facilities to national-defense problems.

Self-justifying typewriter. Following a

design suggested by President Bush, a self-justifying typing machine, to take advantage of the low cost of photo-offset printing, was developed and a successful working model was demonstrated (Root and A. M. Schmidt). Manuscripts may be produced with one typing for immediate reproduction. The device differs from an ordinary typewriter in two essential respects, namely, letter-widths and justification of lines. It makes use of an ordinary printing type-face, and provides for letters of twelve different widths ranging between the small i and the capital M. Typed lines are automatically justified in a single keyboard operation, with no manual setting, by increasing the spaces between words without disturbing the spacing of the letters within the words. The machine "remembers" the line as the operator writes on an electrical keyboard. It then calculates the increase in word-spaces necessary to justify the line, and transcribes the line from the memory-unit to the typewriter, using the calculated spaces. A second memory-unit alternates with the first, one recording while the other is transcribing. The type-font is 12-point monotype Caslon.

Automatic auroral camera. Following investigation of equipment commercially available for use as a camera for automatically photographing auroras at regular intervals, a Bolex 16-mm moving-picture camera was purchased as the photographic unit of equipment for the program at College (Alaska) Observatory. Automatic control mechanism, equipment for developing 100-foot lengths of film, and equipment for monitoring the exposed film were designed, and the apparatus is being constructed in the Department's shop and will be available for use at College in September 1941. Constructive suggestions and advice from the Bolex Service Laboratories, the Eastman Kodak Company, and especially Professor C. W. Gartlein, of

Cornell University, have facilitated this development.

PUBLICATIONS

Publications relating to the geomagnetic researches are listed in the bibliography at the end of this report.

Increased interest in geomagnetism during the year is evidenced by meetings and conferences at which lectures and addresses were presented. Among these may be mentioned the following: The Kelvin Lecture to the Institution of Electrical Engineers at London, "The Sun and the ionosphere," was delivered by Chapman; Chapman also presented the first Charles Chree Address, at London, dealing with (1) Charles Chree and his work in geomagnetism, (2) geomagnetic time-relationships, and (3) the future of world magnetic surveying, and was awarded the first Chree Medal and Prize. In a Symposium on Geomagnetism, under the auspices of the American Philosophical Society and Girard College, in commemoration of the life and work of Alexander

Dallas Bache, Fleming gave the evening lecture on "Geomagnetism: World-wide and cosmic aspects with especial reference to early research in America." The following papers were presented: "Terrestrial electricity in relation to geomagnetism," by Gish; "Magnetic work at sea," by Johnston; "The significance of fossil magnetism," by McNish; "Contributions of ionospheric research to geomagnetism," by Berkner; "Cosmic rays and geomagnetism," by T. H. Johnson. In the Conference on Solar and Terrestrial Relationships at Harvard College Observatory, June 2, 1941, McNish spoke on "Solar effects on geomagnetism," and at the annual meeting of the American Geophysical Union, April 30, 1941, on "Geomagnetic survey of the volcanic areas of Guatemala." Bartels addressed the Prussian Academy of Sciences, February 10, 1941, on "Variations of solar radiation inferred from geomagnetic observations." Material was supplied by Berkner for a release by the Institution on "Electrical layers in the atmosphere."

TERRESTRIAL ELECTRICITY

Because of the operation of observatories, considerable time is necessarily spent at Washington in work of a routine nature; a good share of this was done by the regular personnel of the Section of Experimental Work in Terrestrial Electricity, namely, Gish, Rooney, Sherman, Torreron, and Wait. Since early in 1941 Rooney and Torreron, being temporarily employed full time on national-defense projects, have not been active in this work or in the investigations of problems of terrestrial electricity. This loss was partially offset by contributions made by Mrs. Marcella Lindeman Phillips, guest physicist since December 2, 1940.

ATMOSPHERIC ELECTRICITY

The investigations outlined below are immediately concerned not with the conspicuous electrical phenomena of thunderstorms, but with electrical phenomena and properties of the atmosphere prevailing during fair weather, and are directed toward the elucidation of fundamental aspects of atmospheric electricity.

Measurements of the electric field-strength, or potential-gradient, and of the electrical conductivity in the air near the Earth show that most of the time, whenever fair weather prevails, an electric current (air-earth current) flows from the

atmosphere to the Earth, and that for the whole Earth the aggregate current is about 1800 amperes. It is also apparent from such measurements that this current must be compensated by an oppositely directed current (supply-current), whose origin is not yet definitely ascertained. Investigations which help to ascertain the origin of the supply-current are accordingly of importance for their bearing on a fundamental problem of atmospheric electricity. That the aggregate supply-current varies in a fairly regular manner during the day is also definitely shown by data for the air-earth current. On an average the range of this diurnal variation amounts to about 30 per cent of the mean, the greatest intensity occurring at about 19 hours after Greenwich midnight. If one could find a place where the air-earth current was unaffected by local circumstances, then a continuous record of this current would show how the aggregate supply-current varies from time to time. Since no such place has been found, it is necessary to resort to one or more of several devices. Thus, for example, (a) one may endeavor to avoid making measurements at a place where large local disturbances are expected, (b) one may eliminate some of the local effects by dealing with suitably chosen averages of data, or (c) if the local effects are adequately determined and understood, allowance may be made for these. In fact, some knowledge of the source and nature of these local effects is required in order to make most effective use of devices (a) and (b). The extension of such knowledge is a prime objective of a good share of the investigations in progress.

The air-earth current during fair weather is usually assumed, as in this report, to consist chiefly of the drift of ions in the electric field (electric conduction-current), but it is estimated that during the fall of heavy rain the transport of electricity by

falling drops (electrical convection-current) may considerably exceed the electrical conduction-current. If in fair weather appreciable electrical convection were effected by, say, the mixing action of wind, then the assumption that the air-earth current is adequately represented by the electrical conduction-current would not be valid. Fortunately the outcome of a further investigation of the role which turbulent mixing of the air may play in atmospheric-electric phenomena, made during the year (Gish), indicates that, except in uncommon circumstances, the air-earth current-density, i , may be regarded as equal to the electrical conduction-current-density—the latter being determined by the electric field-strength, E , and the electrical conductivity of air, λ , as measured at some point in the atmosphere, or, quantitatively, $i = \lambda E$. The air-conductivity depends on the concentration of ions in the atmosphere and on the mobility of these ions (the velocity they attain when acted upon by an electric force of unit-intensity). Ions with positive charge contribute a component, λ_1 , and those with negative charge contribute another component, λ_2 ; or, $\lambda = \lambda_1 + \lambda_2$. The three separate elements, E , λ_1 , and λ_2 are recorded continuously at the Institution's magnetic observatories. These data afford a fairly complete record of the electric conduction-current. Although the air-earth current can be directly measured, the method is not well suited for use in continuous registration, and, furthermore, it is advantageous for analysis and interpretation to know how the individual elements vary.

The factors on which the elements E , λ_1 , and λ_2 depend are also subjects for special investigation because the information obtained helps to clarify the more general phenomena of atmospheric electricity as well as some aspects of other geophysical phenomena. That information regarding

these factors is also occasionally required for the correct interpretation of phenomena which are of immediate practical concern, or for effectively planning the investigation of these, was again emphasized during the year by the number of specific cases that were presented for advisement. The concentration of the ion-population in the atmosphere; the character of the ions; the rate at which ions are formed, destroyed, or removed from a given space in the atmosphere; the part played by certain molecular aggregates (nuclei of condensation) in determining the concentration of that class of ions on which air-conductivity chiefly depends—these are also topics on which the items in this report have bearing.

Electrode-effect. The electric field which prevails during fair weather causes positive ions to drift toward and negative ions to drift away from the Earth, and since negative ions are not supplied to the air from the Earth at a sufficient rate, if at all, the concentration of negative ions in air near the surface is thereby diminished to an extent which depends on the strength of the electric field, if other factors remain unchanged. Since, however, positive ions drift toward the Earth from the large reservoir of air above, the concentration of these is not directly affected in this way. As a result the concentration of positive ions in the air within a meter or so from the Earth exceeds that of negative ions. From considerations based on the most general quantitative theory of this "electrode-effect" thus far developed—namely, that of Scholz with minor extensions made by Gish and Sherman—Sherman showed that the concentration of positive ions (or that of negative ions when the electric field is reversed) in air adjacent to the Earth may be greater than, equal to, or less than that in air a few meters above according to the value assigned to one of the

parameters which appear in the equations. This parameter is the coefficient of combination of small ions with Langevin ions, and it is therefore important apart from this particular theory. What follows is of interest because the values for that coefficient which have heretofore been found are discordant.

From an inspection of the registrations of air-conductivity obtained at the observatories of the Department, it is noted that at intervals during thunderstorms, when intense electric fields occur, one component of conductivity is reduced to a small fraction of the normal value, whereas the other suffers no noticeable change. This observation, together with the relation found by Sherman, leads to the inference that the coefficient of combination is nearly the same at all these observatories and is approximately equal to 5.4×10^{-6} , provided the electrode theory is valid. The theory has been found to be in satisfactory quantitative agreement with data obtained at College, Alaska, during calm weather, but not with those for windy weather (Gish and Sherman, Year Book No. 38, p. 75). A preliminary quantitative examination was therefore made, during intervals when there was little wind (Sherman), of a number of these intervals recorded at the Tucson Magnetic Observatory. This examination shows that there is a high correlation between the electric field-strength and one component of conductivity, but no significant correlation between field-strength and the other component during a particular field-disturbance. The value (5.4×10^{-6}) indicated by this line of evidence is well within the extremes reported for this coefficient.

From an examination of data from Watheroo in the light of the theory of the electrode-effect, Wait concluded that in a general way the following characteristics may be accounted for on the basis of the

electrode-effect: (a) an increase in the ratio of positive to negative conductivity during times of low wind-velocity and during times of smoky as compared with non-smoky conditions; and (b) an increase in potential-gradient and a decrease in conductivity during smoky as compared with non-smoky conditions.

Combination of large ions. Records of rate of small-ion formation (with thin-walled vessel) and of small-ion and large-ion content (with small-ion and large-ion counters) inside a closed room have permitted an estimate of the combination-coefficient between small and large ions (Wait). The value determined is around 5×10^{-6} to 6×10^{-6} , whereas the value obtained for the large-ion recombination-coefficient for more or less simultaneous times was from 1.0×10^{-8} to 0.5×10^{-8} . Extension of Harper's deductions suggests that the radius of large ions is around 10^{-6} cm.

Rate of ionization. Although it has not yet been feasible to include, in the program of the observatories, measurements of the rate at which small ions are formed in the air, such data would enable one to make more definite interpretation of some of the electric phenomena. It was shown by Sherman last year, however, that estimates of this element, as well as of the concentration of condensation-nuclei, can be made from data for λ_1 , λ_2 , and E , using relations developed from the theory of the electrode-effect, provided the data are obtained during periods when there is so little wind that eddy-diffusion plays a negligible role in the distribution of ions. Estimates made in this way by Sherman last year, using data obtained during the extraordinarily calm winter months at College, Alaska, seemed to justify the making of such estimates from data obtained at the Watheroo Magnetic Observatory during periods of calm. In the course of

the calculations one also obtains estimates of the concentration of condensation-nuclei. The estimates (Wait) of these two elements indicate a correspondence in their variations and are accordingly conveniently described jointly. The rate of ionization appears to vary inversely as the concentration of nuclei. The latter, as is to be expected, is greater on smoky days than on days without smoke, and is least during the cool, moderately rainy weather of the winter at Watheroo.

The average rate at which ions are formed in a closed vessel is of course readily measured, but values found in this way doubtless differ considerably from the actual rate in the atmosphere even when the walls of the vessel are made from the thinnest available material. Using the thinnest commercially available cellophane, results of considerable interest have been obtained in previous years, but experiments and calculations made during the year (Gish, Sherman, Wait) bring into question the corrections which have heretofore been applied to the measured values. The residual range of alpha particles after passing through the cellophane is considerably less than was previously estimated. Improvement in this respect was effected by using aluminum foil of about the same thickness as the cellophane. Measurements of the rate of ionization that are in error by a constant factor or by an additive constant would be an aid in some investigations even though the constants were not accurately determined, but for reasons which follow, Gish concluded that the actual case is not quite so simple. According to estimates (made by Professor V. F. Hess some years ago) based on the average concentration of radioactive matter in the Earth and in the air, almost half the ionization in the atmosphere near the surface of land is attributable to alpha rays from radioactive matter in the air and

about an equal amount is attributable jointly to gamma radiations from radioactive matter in the Earth and to cosmic radiation. At a given place the intensity of the cosmic radiation seldom varies more than a few per cent, hence the part contributed to the rate of ionization by this factor should not vary much. The greatest variation is expected in the part contributed by the alpha rays, since that depends on the rate at which the radon and thoron gases escape from the soil and on the rate at which the radioactive matter is dispersed in the atmosphere. The part contributed by the gamma radiation doubtless also depends somewhat on the latter, being smallest at times when the radioactive gases escape most rapidly. At these times the alpha-ray component would be greatest, provided the rate of dispersion has not increased correspondingly, and there should be a negative correlation between the alpha-ray and the gamma-ray components. Apparently, then, the relations between these components are not sufficiently simple and dependable to admit the possibility of obtaining a correct value of the rate of ionization in the atmosphere simply by applying a correction to direct measurements of the rate of ionization in a thin-walled vessel. By using two vessels simultaneously, however, the one admitting no alpha rays but being practically transparent for the other rays, whereas in the second vessel a considerable proportion of the alpha rays are admitted, the part contributed by alpha rays in the latter can be determined and this, corrected for absorption and geometrical factors, then added to the value obtained with the first vessel to obtain the desired result. This assumes that the residual ionization, due to radioactive impurities in the walls, is negligible in both vessels; otherwise that component must be determined, which is feasible only if it is essentially constant.

Eddy-diffusion, or stirring by turbulent wind, affects atmospheric-electric phenomena by rapidly dispersing electric charges, ions, and condensation-nuclei from places where the concentration is high relatively to the surroundings. When this factor is taken into account, the equations for the equilibrium-distribution of ions in the atmosphere are generally not soluble, but the solution for a special case was mentioned last year. For the nuclei of condensation, solutions of more general import have been found, but data which would serve as a direct test of such solutions were not available until the publication (E. A. Yunker, *Terrestrial Magnetism*, vol. 45, pp. 121-126, 1940) of registrations of nuclei-concentration at two levels in the air at Palo Alto, California. A quantitative examination (Gish) of the published results shows that in broad outline these data are consistent with the view that nuclei (*a*) are introduced into the air at some more or less distant place, (*b*) are carried along by the wind some tens of meters above the surface, and (*c*) are diffused vertically and laterally by the turbulent air, the concentration being greatest at some undetermined level and decreasing in either direction along the vertical. There is a flux of these nuclei toward the Earth, where some are deposited and lost from the atmosphere; ordinary settling is doubtless negligible as compared with this. No appreciable proportion of the nuclei comes directly from the Earth at this place. In the first three months of registration the level of maximum concentration was evidently higher than 20 meters—the upper level at which data were obtained—but in the last two months (June, July) it must have been at a lower level if the distribution was brought about by eddy-diffusion. These data, however, do not supply a simple and at the same time convincing illustration of an effect of eddy-diffusion.

If the distribution of nuclei at this place depends chiefly on eddy-diffusions, the nuclei must at times come from at least two distinguishable sources, and, furthermore, the coefficient of eddy-diffusion at this station must depend to a considerable extent on a variable other than the wind-velocity; perhaps the roughness-factor depends on the direction of the wind.

The reliability of condensation-nuclei counts. The novice at counting nuclei of condensation is likely to entertain an unjustified distrust of his results because the counts vary so much. He may think either that the instrument is defective or that the concentration of nuclei in the air undergoes such large and erratic variations from minute to minute that the counts are of doubtful value. But when he comes to make a statistical examination of his data he may find that the variation is less than one has a right to expect even if the average concentration of nuclei in the air from which one takes samples is invariable. At any rate such indications have been found by several investigators who have made the examination required to reveal them—a result which may have disturbing implications and which impels one to inquire whether some defect of instrument or technique has interfered with the randomness that the counts may be expected to display. Data suitable for making such an inquiry were obtained during the year (Gish and Phillips). This study showed again that the variance of the counts is less than the mean count, whereas from simple probability theory one would expect it to equal or exceed the mean. No significant dependence of this on any one of a variety of experimental factors was found. It is the same (*a*) for the several observers whose data were examined, (*b*) for the two different instruments of the same type (Aitken pocket nuclei-counters), (*c*) for the counts on the first, second, and third

successive expansions of a given sample of the air that is being examined, (*d*) for uncharged and for a mixture of charged and uncharged nuclei. These observations suggest that something more fundamental is involved.

Adsorption of condensation-nuclei in ducts. In certain experiments in which the air to be examined is carried through ducts, some investigators have found that a fraction of the nuclei are lost, whereas others report that none is lost. An explanation of at least some of these contradictory results was provided by experiments made during the year (Gish and Phillips) which show that the adsorption depends on the geometry of the ducts. Apparently when the turbulence of the air-stream is reduced the adsorption is also reduced. The process of adsorption may be viewed as follows: In the thin mantle of relatively quiescent air adjacent to the walls of the duct, nuclei approach near enough to adhere to the walls chiefly by virtue of their Brownian movement. The rate of adsorption then will be proportional to the nuclei concentration-gradient in this mantle. This gradient is greater when the main air-stream is turbulent because the resultant stirring maintains a high concentration of nuclei in the air adjacent to the mantle and also reduces the effective thickness of the quiescent mantle. This investigation was made primarily for its bearing on measurements designed to determine the proportion of nuclei which are uncharged. For this purpose air is drawn through a cylindrical electric condenser which removes all charged nuclei when an electric field is maintained between the elements. Counts are made of the nuclei in samples of air taken alternately at the entrance and at the exit, the latter both with and without an electric field in the condenser. Adsorption is revealed by comparing the count made at the entrance with that made at the exit

when the condenser is without an electric field. The ratio of the counts made at the exit with and without electric field, respectively, would equal the proportion of nuclei which are uncharged provided charged and uncharged nuclei are adsorbed with equal facility. But the assumption implied in this has not yet been justified by actual tests. Valid tests would be supplied by counts made at the entrances and exits of two condensers, arranged end to end in the form of a continuous duct, for the several combinations of "no field" and "with field," only if it is permissible to assume that the ratio of adsorption of charged to that of uncharged is the same in both condensers, and if the field has no influence on the adsorption of the uncharged nuclei. It was found, however, that the adsorption in the downstream condenser was reduced so much—doubtless as a result of reduction of turbulence by the fore condenser—that the test was inconclusive. A different kind of test for this is in progress.

The proportion of nuclei which are uncharged. Data obtained in the course of the experiments described in the preceding section verified the rather large value (0.75) for the fraction of the nuclei which are uncharged found in previous years in this laboratory. These values, calculated on the assumption that the proportion of nuclei adsorbed is the same for the charged and the uncharged, showed no significant dependence on the percentage of nuclei adsorbed, the value being 0.726 for conditions producing the greatest adsorption (19 per cent) and 0.736 for those giving the least adsorption (5.3 per cent).

Behavior of Aitken pocket nuclei-counter. Early in the investigation outlined above, tests made to determine whether it is necessary to stir the sample of air admitted into the counting chamber showed that for this counter stirring is

required in order that the sample of nuclei-bearing air may become thoroughly mixed and diluted with the pure air in the chamber. This is contrary to the conclusion reached by Scrase in England, but his tests were made with a counter which inhales the sample in a way that obviously effects more stirring than is the case with the Aitken pocket nuclei-counter, especially when the latter is used for counts in small samples.

It has been a moot question whether the droplets which fall on the counting stage—the entities actually counted—were all formed by the water-vapor condensing on the relatively large nuclei of condensation exclusively; some writers state that small ions of molecular size also serve as nuclei for a portion of these droplets. This claim is now refuted, as concerns the Aitken pocket counter as normally used, by the following observations: (a) With repeated expansion, the air in the counting chamber approaches a state when no further droplets fall; (b) when the air in the counter is brought into that state, no droplets fall after the counter has been left standing for an indefinite period of time (tests have been made many times after the counter had stood overnight or over the week-end); (c) there is no increase in the count when a milligram of radium is held near the counting chamber.

Some persons who use nuclei-counters count only the drops which are precipitated by the first expansion. That practice is justified only if the drops which are usually found to fall on later expansions do not represent nuclei that were originally present in the sample and not previously precipitated. A further analysis of the counts obtained on successive expansions shows that this practice is not generally justified and that results obtained in this way are too small; for two pocket-type counters which were studied, the ob-

served value would have to be increased by 59 per cent of itself to give the correct value. The counts on five successive expansions are required to insure that no systematic error greater than 1 per cent arises from this source.

The reliability of values for the electric conduction-current derived from mean values of air-conductivity and of potential-gradient was examined in greater detail than heretofore. The registrations obtained at the observatories are evaluated in such a way as to give the mean, for each hour, of conductivity and gradient, respectively. A value of the conduction-current for each hour may then be obtained by forming the product of corresponding hourly values of conductivity and gradient. A mean of values of current calculated in this way tends to be less than the product of the means of conductivity and of gradient, respectively, for the corresponding period. In this connection it was noted (Sherman) that for two correlated series the mean of the products is less than the product of the means in case of negative correlation. It is generally recognized that values found for the conduction-current usually vary less than at least one of the elements (conductivity and gradient) on which it depends, and consequently these elements are negatively correlated. Though it seems obvious that the greatest accuracy is realized if individual values of current are calculated, to do this adds considerably to the task of marshaling the data. On this account one prefers to use the product of the means ($\bar{\lambda} \times \bar{E}$) rather than the mean of the products ($\bar{\lambda} \bar{E}$), provided the error in doing so is insignificant. A direct comparison (Sherman) of results derived by the two methods, using data from three observatories, led to the following conclusions: (a) As the period over which the means of λ and E are derived increases from 1 to 24 hours, the error in-

creases. By extrapolation from this trend to zero-period, it is estimated that the average error in an individual hourly value of current derived in the manner mentioned above is not greater than 1 or 2 per cent, and it is accordingly deemed unnecessary to evaluate the registrations for periods shorter than 1 hour when the data are to be used for investigation of average characteristics. (b) In the mean for a single day the extreme error was 81 per cent. (c) The error in the monthly mean for a given hour of the day varied from 0 to 29 per cent. If the data for College, Alaska, were compiled in this way, the error in the amplitude of the 24-hour harmonic of the average diurnal variation of the conduction-current would be 22 per cent in winter and 26 per cent in summer. The phase is also affected. Errors of this magnitude are of course too large to ignore when interpreting such results.

Electric conduction-current, Watheroo, 1924-1934. Analyses of the atmospheric-electric data for the 11-year period 1924-1934 (chiefly those for Watheroo) have been made (Wait, Torreson) in connection with the preparation of a general report on the results for that observatory. Some results of these analyses pertaining especially to the conduction-current are as follows:

(a) A seasonal change in the diurnal variation of the conduction-current was disclosed by comparing the average characteristics for the month of January with those for the month of June for the 11-year period. The chief feature of the seasonal change is that the maximum of the 24-hour harmonic, obtained from Fourier analyses, occurs earlier in January than in June, namely, about 3.5 hours as compared with 7.5 hours after local midnight, or 19.5 as compared with 23.5 hours after Greenwich midnight.

(b) Local meteorological circumstances have little effect on the conduction-current.

In a brief survey (Wait) of data for both Watheroo and Huancayo no significant correlation was found between the atmospheric-electric elements and either the temperature or the relative humidity of the air, but a negative correlation between conduction-current and vapor-pressure was indicated.

(c) The presence of smoke in the air at Watheroo is associated with a marked decrease of air-conductivity and a correspondingly large increase in potential-gradient, but a comparison (Wait, Torrison) of conduction-current values obtained on smoky days with those obtained on non-smoky days for the month of March during the 11-year period showed that the conduction-current is affected little, if at all, by day-to-day variations in atmospheric contamination by smoke at this observatory. Obviously the smoke on these occasions does not extend high enough in the atmosphere to affect appreciably the effective resistance of the vertical column of air extending from the surface to a level some tens of kilometers higher. Examination of the components of the conduction-current, namely, that corresponding to the drift of positive ions toward the Earth, i_1 , and that due to the drift of negative ions away from the Earth, i_2 , shows that i_2 is generally decreased and the ratio (i_1/i_2) is increased by the presence of smoke. This is doubtless a manifestation of the electrode-effect.

(d) The columnar resistance of the atmosphere over Watheroo relative to that over the oceans, and temporal variations in this resistance, were estimated (Wait) by comparing data obtained over the open oceans during cruises of the *Carnegie* with corresponding data for Watheroo. These estimates are essentially the ratio of the conduction-current density at sea to that for the station in question. The chief uncertainty in the estimates depends on the

unfortunate circumstance that often the data for the oceans are not simultaneous with those for the land station. Even in those cases, however, the estimates are thought to be an aid to interpretation, because it has long been apparent that atmospheric-electric phenomena at sea are considerably less subject to persistent local or regional disturbing influences than they are at most places on land. Fortunately, in 1928-1929 there were days for which simultaneous data were available at sea and at Watheroo and Huancayo. It is reassuring to find that the resulting estimates of columnar resistance agreed well with those based on data that were not simultaneous. The result of chief interest is that these values vary in a regular manner during the day. The diurnal-variation curves for Watheroo, Huancayo, and Tucson are similar when plotted on local mean time. A maximum is reached around midnight which is about 30 per cent greater than the minimum, which occurs during the forenoon. The character of the diurnal-variation curve remains essentially unchanged throughout the seasons at each station.

Atmospheric-electric elements during bright chromospheric eruptions on the Sun. Usually when, with the spectroheliograph, bright eruptions are observed on the Sun, there are characteristic disturbances of the magnetic field of the Earth, of the electric currents in the Earth, and of short-wave radio transmission ("fade-outs"). Systematic investigation of these phenomena leads to the conclusion that at these times radiation from the Sun produces intense ionization of the air down to considerably lower levels than usual. It is natural to inquire whether the ionization at the Earth's surface is appreciably increased, or whether the more extensive ionization in the higher atmosphere has effected a sufficient decrease of the columnar resistance to bring about detect-

able changes in the electric field at the surface. An examination (Gish) of a number of cases recorded in recent years disclosed no evidence that any changes occur in either the air-conductivity or the field-strength (potential-gradient) on these occasions. All four elements, potential-gradient, λ_+ , λ_- , and i , have recently been examined (Wait, Torreson) for possible effects at both Watheroo and Huancayo. Any direct effect which may take place cannot be greater than a few per cent of the mean values of these elements and can be detected only by a statistical examination of a great many cases. In the light of present knowledge of the electrical conductivity of the troposphere and lower stratosphere, the result of this examination leads one to infer that up to perhaps 20 km there is no marked departure from the normal ionization during these solar flares.

Cooperation and consultation with other investigators. A number of inquiries were received by correspondence regarding one or another aspect of atmospheric electricity which the correspondent thought might have some bearing on the outcome of his investigation or the interpretation of the results. These and other inquiries made by visitors serve to remind one of the recurrent need for information regarding atmospheric electricity in engineering and other fields. Conferences were held at the Department with Nathan Cornfeld, instructor in physics at Long Island University, regarding his preliminary results and plans for his future program for the investigation of factors which determine the distribution of nuclei of condensation in the air near the Earth. Stimulating discussions were held with Professor V. F. Hess, Department of Physics, Fordham University. Gish again served on the Special Subcommittee on Lightning Hazards to Aircraft of the National Advisory Committee for Aeronautics.

GEOELECTRICITY

There has been relatively little activity in this field since January, when Rooney began national-defense duties. The work consisted chiefly in making examinations designed to help in controlling the operations at the observatories, checking and making final reductions and tabulations of the data received from the observatories, and generally putting these in form suitable for further investigation and for publication. Investigation of the electrical activity in the Earth, in relation to the sunspot-period, was extended, and some further examination of geoelectric variation during the lunar day was made (Rooney). The previous indications were verified and improved quantitative results were obtained.

Geoelectric and associated atmospheric-electric disturbances. One investigator (A. W. Lee, England) has reported that a statistical examination of magnetic and atmospheric-electric data for two places (Lerwick, in the Shetland Islands, and Kew Observatory, near London) indicates that during periods when magnetic storms and the associated geoelectric storms are prevalent, the variability of the electric field in the atmosphere tends to be greater than at other times. Similar investigations of data for other places have not yet been made, but many registrations of the electric elements have been inspected without finding evidence of such an association; during the magnetic storm of March 24-25, 1940, the atmospheric-electric elements were quite normal (Gish, *Proceedings of the American Philosophical Society*, vol. 84, pp. 187-204, 1941) at the Department's observatories. If there is any effect, it is small at these places even during an extreme magnetic storm, and the association is doubtless a loose one. Heretofore, no satisfactory way of accounting for such an

effect has been suggested, but during the year an examination was made (Gish) of a mechanism briefly described below.

When a steady electric current flows across the boundary between two bodies which differ in electrical conductivity, a distribution of electric charge is maintained at that boundary. The greater the contrast in conductivity and the greater the intensity of the current, the greater is the density of this charge. Analogues of this are to be found in the Earth and doubtless also in the high atmosphere. For example, between ocean and land the contrast in conductivity is usually very great, and the natural electric currents in the Earth at certain stages traverse the boundary between salt water and land. The sign of the charge established at this boundary and, to some extent, its density will depend on the stage or phase of the great electric eddy of earth-current that has reached this boundary at a given time. At the surface of the Earth near this boundary the surface electric charge maintained in this way may be manifested by a modification of the electric field in the adjacent air. These modifications would seem to be in qualitative accord with the indications already mentioned. They should probably be most readily detected at a coastal station located in a suitable latitude, whereas over the open sea or over land areas where the electrical conductivity varies little from place to place no appreciable modifications of field should be expected from this source. From this viewpoint, it is conceivable that even at a favorable place the

correspondence between a disturbance of the electric earth-current and the resulting disturbance of the atmospheric-electric field would be subject to large random variations; for a given value of the former, the latter may be positive, negative, or zero, depending on what part of the wandering electric earth-current eddy is at the place when the disturbance occurs. Estimates of the possible magnitude of this effect have been made for some simple ideal cases. These estimates indicate that the effect may sometimes be large enough to be detectable by suitable statistical method at some places on the Earth. If charges are maintained in a somewhat analogous manner in the high atmosphere, the variability of the electric field near the Earth, though showing the random aspect, should be alike, on the average, for all stations in the same latitude.

PUBLICATIONS

Papers relating to terrestrial electricity which were published during the year are included in the bibliography at the end of this report. The following (not yet published) were also presented: "Terrestrial electricity in relation to geomagnetism," by O. H. Gish, American Philosophical Society, February 1941; "Errors in measurements of condensation-nuclei," by O. H. Gish and Marcella Lindeman Phillips, and "Diurnal variation in electrical resistance of the vertical column of the atmosphere at Watheroo, Western Australia," by G. R. Wait and O. W. Torreson, American Geophysical Union, April 1941.

INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO PROBLEMS OF GEOMAGNETISM

Geomagnetism consists of two parts, the magnetic field of the Earth's interior and the magnetic field produced by electric current-systems outside the Earth. It is

known from the theoretical work of Gauss, as extended by Stewart and Schuster, that certain changes in geomagnetism must have their origin, in part at least, in the

outer atmosphere. Investigation of the electrified part of the high atmosphere—the ionosphere—where exists the ionization on which these current-systems depend is therefore an essential part of research in geomagnetism. Ionospheric investigations of the Department are directed toward disclosure of fundamental relations between electrical conditions in the Earth's outer atmosphere and geomagnetic changes which arise there.

The existence of these ionized regions was experimentally demonstrated in 1925 at the Department by Breit and Tuve. Subsequent developments in equipment and technique have permitted thorough and systematic ionospheric observations at several localities. The character of these highly ionized regions has been found to be much more complicated than was originally supposed, with three major ionized strata in evidence. Measurement of change of ionization with time at a particular latitude or location gives one cross-sectional description of complicated effects which can be observed. Such observations are representative of the type of research done at the Department's observatories at Huan-cayo and Watheroo, but other types of observation are necessary to obtain the proper perspective of all the atmospheric phenomena involved in geomagnetism. Of these other observations, those on changes with latitude or location in general are among the most important in formulation of a complete picture of conditions as they exist.

RESEARCH AND DEVELOPMENT

Observatory at College, Alaska. The most important effort in ionospheric research during the year was the preparation for, and inauguration of, the expeditionary observatory, in collaboration with the University of Alaska, at College, Alaska. President Bunnell of the University, and

Professor Bramhall, head of the University's Department of Physics, gave active cooperation and assistance. The installation was made under the supervision of Berkner and Seaton, of the Department, the former being Physicist-in-Charge. The Observatory is on the campus of the University of Alaska, about 5 miles west of Fairbanks (latitude $64^{\circ} 51' 27''$ north, longitude $147^{\circ} 49' 20''$ west), and is ideally situated in the zone of maximum auroral activity. It provides for continuous observation of the ionosphere, of the Earth's magnetic field, of the aurora, and of radio-signal intensity from distant points. In fact, practically every method of observation bearing on the ionosphere is being used.

The University provided approximately 1000 square feet of space in the Eielson Memorial Building, adjacent to the Physics Laboratories, and special construction necessary to provide for ionospheric laboratory, recording laboratory, darkroom and film-processing rooms, and offices where computations and analyses are made. The magnetic absolute and variation laboratories constructed for the program of the Second International Polar Year were reconditioned and replaced on the exact site of the Polar-Year Observatory.

The Department provided all equipment, instruments, and personnel for the Observatory. The equipment includes automatic ionospheric equipment no. 3, previously used at the Kensington Experimental Station, magnetic instruments, recording and photographic equipment, and other necessary appurtenances.

Installation began on May 19, 1941, following about two weeks of preliminary survey and planning at the University. Operation of the ionospheric equipment began on June 26, 1941, with other parts of the program beginning shortly thereafter. One year of continuous operation is

planned. All data are being reduced and analyzed at the Observatory so that new phenomena can be studied during operation. The installation has been made with emphasis on reliability, so that no interruption may be permitted to reduce its effectiveness. It is yet too early to report any results of the program, but at least two new phenomena, previously unobserved, have been evident. These will be reported following further analysis.

Systematic ionospheric changes during magnetic disturbances. Systematic ionospheric changes have been found from analysis of two years of data at Huancayo and at Watheroo. Quoting from the publications on this subject: "At Huancayo, electron-density at level of maximum increases continuously as magnetic activity increases up to character-figure 2.0. We place no great emphasis on the slight break in the curve, because of the small number of days during which great magnetic activity occurred. It is significant, however, that the break in the curve remains when the data are separated into two parts. There appears to be little if any seasonal change in the character of the relation at Huancayo.

"At Watheroo, the relation is quite opposite to that at Huancayo during months between September and April (generally speaking, in the summer months at Watheroo). Here the average ion-density at level of maximum falls continuously as magnetic activity increases. During the winter months, electron-density rises for slight to moderate magnetic activity, and then falls as magnetic changes become severe. The relation at Watheroo between maximum electron-density of F_2 -region and geomagnetic activity appears very similar to that already described for Kensington for the same seasons. Likewise, it agrees with the earlier observations of Apleton and his colleagues at Tromsö and

Slough. It is probable, therefore, that the curves for Watheroo can be considered generally representative of the seasonal change in average maximum electron-density of the F_2 -region with geomagnetic activity in both north and south temperate zones, and perhaps, to some extent also, in polar regions.

"It is perhaps surprising to find that ion-density is related to even the smallest magnetic activity, for the curves show definite significant changes at both observatories down to magnetic character-figure zero. This indicates with certainty that the small magnetic character-figures, reported for relatively quiet days, are significant. As a consequence, the normal does not occur for $C_A=0$ (C_A is the character-figure as derived from records at seven observatories maintained in United States, Western Australia, and Peru by the United States Coast and Geodetic Survey and the Institution), but during most months for $C_A=0.3$ to 0.4. In winter at Watheroo, normal is reached again for values of C_A in the neighborhood of 1.3 with relatively small deviations from normal for magnetic character less than 1.3. It must be realized, of course, that the level of magnetic activity at which normal occurs must be dependent upon the average level of magnetic activity over the interval."

Ionospheric disturbance during great magnetic storms. Ionospheric changes during great magnetic storms do not always follow the same general pattern. The ionospheric disturbance during the intense storm of March 24, 1940 was described in the report of last year. Subsequent analysis of this storm has led to certain important conclusions. It was found that at Huancayo, the electrons in F_2 -region were swept out during the initial phase of the storm, diminishing in density at the level of maximum at a rate of at least 1000 electrons per cubic centimeter per second dur-

ing about 45 minutes before the F_2 -layer disappeared. For the next 45 minutes a new layer appeared where the old had been, apparently through normal ultraviolet processes. The rate of increase of ionization indicated a value of recombination-coefficient in F_2 -layer near level of maximum ionization between 1.8×10^{-10} and 2×10^{-10} , with a rate of production at this level of about 230 electrons per cubic centimeter per second. Following this interval, the maximum density increased at an enormous rate corresponding to a production of 1700 electrons per cubic centimeter per second above normal. It was as if the electrons which had been blown out during the initial phase of the storm were falling back into the layer to bring about this great increase in density. There then followed an interval during which the maximum oscillated up and down in density at almost regular periods of 3 hours' duration until the end of the disturbance.

The time-coincidence of ionospheric changes at the two observatories during the storm was of particular interest. As closely as can be determined, the maximum ion-density at both started to fall at the same time. The time at which this occurred at Watheroo could be determined most accurately and was 15^h 59^m GMT—15 minutes after the first large magnetic movement. The exact time at which ion-density began to fall at Huancayo could not be so well determined, but was between 15^h 50^m and 16^h 00^m, that is, in a range between coincidence and 9 minutes before Watheroo.

Changes in height showed no such agreement. There were some abnormal fluctuations before the main magnetic disturbance, as described earlier. The minimum virtual height of the F_2 -layer at Huancayo moved up sharply almost simultaneously with the first major magnetic movement; at Watheroo the sharp upward

rise followed between 30 and 40 minutes later. This time-difference appears significant. Whereas at Watheroo the sharp rise in height lagged behind that at Huancayo, it was preceded by the two significant disturbances, (a) a spatial movement in rise of height from north to south, indicated by the fixed-frequency record, and (b) the more positive evidence of spatial tilts of the isoionic surfaces which immediately followed; finally, the heights rose sharply.

During the other two great magnetic storms of recent years, violent upward movements and disappearances of the F -region at Huancayo were observed, and these both at night. If Huancayo is representative of the equatorial belt generally, it may be presumed that a similar movement takes place everywhere near the equator at the time of beginning of great magnetic changes. Therefore, it seems probable that such a movement took place in the equatorial belt to the northward of Watheroo as well as at Huancayo. The sequence of events suggests that the spatial movement from north to south observed at Watheroo was directly related to the initial upward movement in the equatorial belt.

Ionospheric disturbances associated with magnetic storm of March 1, 1941. The severe magnetic disturbance of March 1, 1941, recorded simultaneously at Watheroo (Western Australia), Huancayo (Peru), and Kensington (Maryland), again offered opportunity for analysis which must lead to a clearer picture of events during magnetic storms.

At Kensington, the associated ionospheric disturbance revealed the development of an ionized layer between the E -and F -regions. The virtual height of this layer was 160 km at 06^h 15^m GMT; by 06^h 30^m its maximum ion-density had increased threefold and its virtual height had fallen to normal E -layer levels near

130 km. Radio reflections from this layer were returned by the normal process of magnetoionic double refraction. Both ordinary and extraordinary wave-components were recorded, and reflection-coefficients were not high. Apparently the condition was not one of simple sporadic *E*-region ionization. Weak and highly scattered *F*-layer echoes were recorded from virtual heights of about 400 km through 09^h 45^m, although *F*-region maximum ion-density appeared to be about normal. From 09^h 45^m through 10^h 45^m the *F*-region was obliterated, although weak and intermittent reflections from *E*-region levels were observed. There appeared to be a slight recovery between 11^h 00^m and 13^h 30^m, when both *E*- and *F*-layers were recorded. The maximum ion-density of the *E*-layer as measured by the penetration-frequency was about normal, but ion-concentration in the *F*-layer was about one-half of normal. The interval between 13^h 30^m and 18^h 30^m was characterized by complete absence of radio reflections of any sort, except for occasional weak or intermittent *E*-region echoes recorded at wave-frequencies below 3.0 Mc/sec. It is significant that this period of greatest ionospheric disturbance closely coincided with the interval of greatest magnetic activity. Between 18^h 30^m and 20^h 00^m, ionospheric records showed slight trend toward recovery, with occasional records of *E*- and *F*-region echoes. After 20^h 00^m ionospheric conditions were rapidly returning to normal except for low *F*-region penetration-frequencies, indicating an apparent deficiency of electrons in the upper region of the ionosphere. These low *F*-region penetration-frequencies persisted through the night until about sunrise (11^h) March 2, following which completely normal conditions were recorded.

At Huancayo, a condition of scattering cleared up about 06^h 15^m GMT and then

the ion-density decreased rapidly to 07^h 30^m. It then increased to unusually high night values at 09^h 00^m. During this interval absorption as indicated by the lowest frequency observed was apparently normal. The *F*-layer "blew up" very rapidly from 09^h 00^m through 10^h 00^m. This condition was associated with low critical frequencies and unusually high ionospheric heights. The effect, however, was of very short duration in that moderately normal conditions obtained after 10^h 30^m. Between 13^h 30^m and 14^h 30^m, the ionosphere was not much disturbed although *F*₂-layer stratification was noted. There were unusually high ion-densities after 15^h 00^m, and another *F*₂-layer stratification was formed by 17^h 00^m. An intense radio fade-out started at 17^h 00^m and all radio reflections were obliterated for more than one-half hour. The over-all effect of the fade-out extended over about 2 hours. During the early evening hours unusually high ion-densities were again recorded without any other apparent indications of appreciable ionospheric disturbance or activity.

At Watheroo, a mild condition of turbulence was recorded at 07^h 30^m GMT and was followed by high values of ion-density to 14^h 00^m. Then the *F*-layer critical frequency dropped rapidly and a condition of sporadic *E*-layer ionization, associated with very low *F*-layer ionization, existed from 15^h 00^m through 07^h 00^m of March 2. During the daylight hours at Watheroo only *E*- and *F*₁-layers were visible to the exploring radio waves; apparently the *F*₂-layer ionization was kept down to such a low value during the daylight hours that it was masked by the *F*₁-region. Normal ionospheric conditions obtained after about 08^h 00^m on March 2.

It is apparent, from the widely different effects observed at the different stations, that systematic analyses of the ionospheric effects associated with magnetic storms for

different locations are necessary to determine the world-picture of conditions in the outer atmosphere which are associated with geomagnetic activity.

Observations during eclipse. Special observations were made at the Huancayo Magnetic Observatory during the solar eclipse of October 1, 1940. The automatic multifrequency ionospheric equipment was operated at double normal speed for about four days, beginning two days before the eclipse, in order that suitable control-data might be had. The Sun was almost totally eclipsed at sunrise. Completion of analysis of these observations should reveal new information concerning ionospheric conditions at sunrise.

Observations during an eclipse are important in determining exact constants for ionospheric theory, for example, recombination-coefficient and rates of production of ionization. These in turn are related to the total amount of ultraviolet radiation which is received from the Sun. Only when these constants are known with precision can ionization at any place and time be calculated with assurance. In turn, the physical properties of the Sun become better defined when the radiation at all wavelengths is determined. Every opportunity for observation during eclipses must be taken to provide factual data necessary to complete the quantitative theory.

Maximum usable wave-frequency for long-distance radio communication. The dependence of high-frequency radio communication on ionospheric characteristics is being carefully examined. Methods are in use whereby ionospheric data obtained from vertical-incidence measurements at one station are translated into terms of the maximum radio frequency which may be used to maintain communication over a given distance. Normally used applications refer to the simplified case of flat Earth and flat ionosphere. The technique

is being extended to include the more accurate cases of curved Earth and curved ionosphere.

The complete data obtained by the continuous operation of multifrequency ionospheric equipments at the Department's observatories make possible reasonably accurate predictions of mean ionospheric conditions for several months in advance. Proper interpretation of such predictions in terms of average conditions of radio-wave propagation represents a service which has important applications.

Instrumental development. An automatic camera with self-contained controls was designed for the auroral program at College, Alaska. Exposures may be made automatically every $2\frac{1}{2}$ or every 5 minutes. Complete records of auroral activity thus obtained will supply needed information as to the mutual causes or effects of auroral, ionospheric, and magnetic activity.

Constant-voltage controllers, for use at the Department's observatories, were completed. These will maintain the direct-current line-voltages within narrow limits of variation, while automatically adjusting the output of motor-generators to assume the variations in load. The controller includes a standard reference-battery at the desired line-voltage. Any change in load on the distributing system produces an unbalance between the standard voltage and line-voltage; this unbalance causes relays to operate through time-delay mechanisms which permit a motor-driven rheostat to adjust the output of the generator so that the line-voltage and standard voltage are balanced. The high degree of voltage-stability inherent in this controller will greatly improve the character of recording at the observatories.

RECORDING AND TABULATION OF DATA

Recording of data. Continuous automatic multifrequency records of iono-

spheric conditions were continued at the Huancayo and Watheroo magnetic observatories and are complete except for short interruptions necessary for maintenance or adjustments. The success in attaining these homogeneous series of data with so negligible losses of records evidences the careful supervision of the relatively complex apparatus at the observatories.

A third multifrequency apparatus was operated at the Kensington Experimental Station from April 1940 to March 3, 1941; this unit was then dismantled and packed for shipment to Alaska. The data at Kensington include material for little-understood seasonal and magnetic effects; the final analyses have been delayed by necessary preparations for the Alaskan project. The installation at Kensington served also for training several observers before assignments for field-service.

Tabulation and publication of data. Scalings of records are completed monthly at each observatory and include tabulations of the hourly values of minimum virtual heights and heights of maximum ion-density of the F_1 - and F_2 -regions, penetration-frequencies of the E -, F_1 -, and F_2 -regions, minimum wave-frequency at which reflections occur, and the squares of the F_2 penetration-frequencies. Daily means and hourly values of monthly means are also compiled and are published quarterly in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, thus being made available promptly to investigators. Annual averages are published at the end of each year. Radio fade-outs, which are occurring with diminished frequency as sunspot-activity decreases, are tabulated monthly.

Personnel. The ionospheric investigations were maintained by Berkner and Seaton at Washington with the assistance of Wells after his return from duty as Observer-in-Charge at Huancayo. Ledig and

Jones also assisted prior to their departure for Huancayo. Berkner and Seaton undertook the installation and operation of the equipment at College, Alaska, with the cooperation of Dr. E. H. Bramhall, Professor of Physics at College, and the assistance of several men employed from the University's undergraduate roll in physics.

COOPERATIVE ENDEAVORS

The annual conference on ionospheric research, scheduled for the spring of 1941, was canceled because of the urgency of matters of national defense. Close cooperation with the National Bureau of Standards and other agencies was continued.

PUBLICATIONS

Papers were prepared as noted in the attached bibliography. Berkner presented a "Suggestion for possible modification of world-wide spectrohelioscope program based on automatic solar-flare indicators" before the Institution's Departmental Group Conference, December 14, 1940. He also took part in the Symposium on Geomagnetism before the American Philosophical Society at Philadelphia, presenting a paper on "Contributions of ionospheric research to geomagnetism," February 15, 1941. Bramhall gave a radio broadcast on "The ionosphere" sponsored by the General Science Department of the University of Alaska, April 19, 1941.

Although some curtailment of analyses and interpretation of theoretical problems is to be expected because of the urgency of national-defense activities, it is felt that the widespread knowledge and understanding of the practical application of ionospheric data to radio communications will result in making more data available from different localities so that the net improvement in scientific knowledge will not be diminished.

MAGNETISM AND ATOMIC PHYSICS

Of the personnel engaged in problems of nuclear physics, Tuve, Hafstad, Roberts, Green, Abelson, and Meyer spent all or most of their time on national-defense work with the part-time assistance of Research Fellows Van Allen and N. M. Smith, Jr. Except for special help and overtime on defense work, Heydenburg and L. Schmidt, with some help by Meyer, carried forward the rebuilding of the large high-voltage tube in the Atomic-Physics Observatory. From March 1941, G. K. Green gave full time to the construction of the cyclotron, completion of which has been requested by government agencies for defense purposes; in this he was ably assisted by D. B. Cowie, assigned from the National Cancer Institute, and by Ksanda, P. A. Johnson, Buynitzky, Caherty, and J. Wright.

EXPERIMENTAL WORK IN NUCLEAR PHYSICS

Investigations of nuclear phenomena continued to have a prominent place in research at physical laboratories throughout the United States and to a lesser extent in countries abroad. The maturing of this relatively new field of study became increasingly evident during the year. Work of an exploratory character has now given way in large part to detailed and accurate studies of complex processes and to the application of radioactive tracers to biological, medical, and chemical problems. Despite the fact that the nature of the forces which bind together the elementary constituents of nuclei is still inadequately understood, there exist several well recognized experimental approaches to the problem of fundamental nuclear forces.

Van Allen and N. M. Smith, Jr., concentrated the facilities of the 1-million-volt

laboratory on the study of one of the simplest of the situations in which the elementary heavy particles exhibit their properties, namely, the splitting of the heavy-hydrogen nucleus (the deuteron) into a proton and a neutron by irradiation with high-energy gamma rays. This splitting process was first observed by Chadwick and Goldhaber in 1935 soon after the successful isolation of heavy hydrogen; quantitative investigation of the phenomenon since then has been meager because of the difficulty of the measurements and the lack of suitable gamma-ray sources. Of the known natural gamma-ray sources only one, thorium C'', is suited to measurements of the type contemplated. Earlier work in this laboratory and elsewhere has shown, however, that there is an important class of artificial nuclear reactions in which high-energy gamma rays are produced by bombarding certain elements with protons. The radiations resulting from the proton-bombardment of fluorine and of lithium are notable for their monochromicity and high energy. These sources were therefore selected for these experiments.

It was first necessary to establish the absolute intensity of the fluorine source. Studies of the reaction have revealed that the number of gamma-ray quanta has a one-to-one correspondence with the number of a monoenergetic group of alpha particles. This fact is of first importance because alpha particles can be counted with accuracy, whereas the direct determination of the quantum intensity of a gamma-ray source involves many difficulties.

A specially constructed variable-pressure absorption-cell ionization-chamber was used in the calibration. It was found that the absolute yield of 6.2 million electron-volt quanta is $(3.74 \pm 0.2) \times 10^6$ per micro-

coulomb of 1050-kv protons bombarding a thick target of calcium fluoride. Lack of knowledge of the absolute quantum intensity of simple gamma-ray sources has long been a barrier to the quantitative investigation of high-energy photoprocesses. It is believed that this calibration of the absolute intensity of the fluorine source will make possible greatly increased activity in this field. The relative ease of comparative intensity-measurements gives it evident value as a calibrating standard.

Preliminary measurements comparing the lithium and fluorine sources indicate $(1.0 \pm 0.2) \times 10^5$ quanta per microcoulomb of 500-kv protons bombarding metallic lithium. The radiation from this reaction is monochromatic (or very nearly so) and is of energy 17.4 million electron-volts. The lithium source has excellent promise for photonuclear studies. We are indebted to Drs. H. E. Merwin and E. S. Shepherd, of the Geophysical Laboratory, for advice and assistance in selecting calcium fluoride crystals used in the gamma-ray program.

Exploratory measurements on the splitting of the deuteron with fluorine radiation had been made during the spring of 1940, and the use of a pressure ionization-chamber filled with deuterium gas had been shown to be a feasible technique.

On completion of the gamma-ray calibration, the photodisintegration studies were resumed with improved arrangements. The smallness of the effect which was being measured necessitated painstaking precautions to assure validity of the determinations. The most important quantitative characteristic of a nuclear process produced by bombardment or irradiation is its probability of occurrence under specified experimental conditions. This characteristic can be described, independently of the detailed arrangement of apparatus, by giving the numerical value of the "cross-section" for the process, that

is, the effective size of the target particle with reference to a particular bombarding particle. Understanding of the photodisintegration of the deuteron requires knowledge of (1) the cross-section for the process (that is, the size of the deuteron as a target for photodisintegration by a gamma-ray quantum) and (2) the angular distribution of the fragments (proton and neutron) with respect to the gamma-ray beam.

Two careful series of measurements place the cross-section for the process at $(11.6 \pm 1.5) \times 10^{-28}$ cm² for quanta of 6.2 million electron-volts. Only one previous determination, that of von Halban using Th C¹¹ radiation, is of comparable accuracy, and for this the gamma-ray energy was only 2.62 million electron-volts. This result is important because of its bearing on several recent theoretical papers dealing with the general problem of nuclear forces with especial reference to the photodisintegration of the deuteron.

The experimental value given above is distinctly lower than any present theory predicts. The direction of the discrepancy indicates either that the radius of effectiveness of nuclear forces may be much less than was heretofore believed, or that it is dependent on the relative velocity of the particles involved. This doubt as to the correctness of existing nuclear theories is strengthened by the recent experiments of Alvarez at the University of California on the scattering of very slow neutrons by ortho- and para-hydrogen and by those of Wilson and Creutz at Princeton University on high-energy proton-proton scattering. These results have been discussed with Professors Bethe, Breit, Oppenheimer, Schiff, and Teller.

Preliminary experiments on the best mode of approach to the associated angular-distribution problem mentioned above were made. It appears that the best technique will be the use of a thin layer of

deutero-paraffin or of heavy water in conjunction with special photographic plates of the Eastman Kodak Company.

Incidentally there was discovered a new type of nuclear process, namely, the emission of protons when certain elements are irradiated with the very high-energy gamma rays from lithium.

The magnitude of the bombarding beam in the 1-million-volt apparatus was improved more than fivefold by the installation of faster oil-diffusion pumps on the vacuum-tube and the use of a palladium purifier in conjunction with the ion-source.

The facilities of the Atomic-Physics Observatory have the greatest potentialities for improving and extending the experimental knowledge of the photodisintegration of deuterium. First, bombardment of fluorine with 3-million-volt protons yields over 50 times the gamma-ray intensity available with the 1-million-volt machine. Second, the accelerating tube of the Atomic-Physics Observatory can be used in the production of a beam of high-energy electrons of readily controllable energy. The X-rays which they produce when allowed to strike a target will be excellently suited for the study of the angular distribution of the photo products near the energy-threshold for the process (2.2 million electron-volts). This problem is regarded by Professor H. A. Bethe as one of the foremost in nuclear physics.

ATOMIC-PHYSICS OBSERVATORY

Since evidence had shown that the vacuum accelerating tube was the main limitation on voltage of the high-voltage generator, the tube was removed during the summer of 1940. The generator was then run with 50 pounds air-pressure in the tank to observe again the limiting voltage without the tube. This limit was found to be 4.5 million volts, although measure-

ments made when the generator was first erected without a tube showed voltages above 5 million. The present voltage-measurement is more accurate, since during the operation of the accelerating tube the voltmeter had been calibrated in terms of the gamma-ray resonances of fluorine and aluminum and changes had been made in the voltmeter to give a more linear response at the higher voltages.

The failure of the generator above 4.5 million volts seemed to occur both along the surface of the charging belt and along the porcelain insulating columns at their junction with the large corona rings. Other laboratories have reported improvement resulting from the introduction of horizontal equipotential surfaces, close to the surfaces of the belt, in the form of rods or idler pulleys connected to the corona ring-system. Such equipotential rods and one central idler pulley were installed along the belt of the generator at 44-inch intervals, this interval corresponding to the position of the intermediate steel platforms of the supporting columns. This change, however, gave no appreciable improvement in the voltage-limit of the generator.

An attempt was also made to improve the field-distribution along the porcelain supporting columns by enlarging the corona rings. These rings are now 4 inches away from the porcelain columns and are held to them by a system of rods and wires. Steel disks were also placed around the porcelain, contacting the corona rings, to give definite equipotential surfaces along the porcelain legs. There are corona points between these plates for grading the potential down the column. Tests are now in progress to determine the effect of these improvements on the voltage of the generator.

Tests on vacuum-tube designs were made. Following a number of alterations

in the old tube, an arrangement using the old porcelains was evolved which, on tests of 7-foot lengths, showed improvement of almost 50 per cent over the old tube in breakdown voltage. This design uses twice the number of accelerating electrodes and includes baffles inside the tube to cut down the electron path-lengths in the tube. Tests were also made of a 7-foot tube of small diameter with re-entrant electrodes, of a type designed by Herb at the University of Wisconsin, which Professor Ellett has constructed for the new pressure generator at the University of Iowa; this tube was superior to other designs tested from the standpoint of peak-voltage without an ion-beam down the tube. It was decided to rebuild the accelerating tube according to the modified arrangement using the original porcelains. This is under way and it is hoped that the accelerating tube may be installed soon.

CYCLOTRON

The new cyclotron laboratory was completed except for some of the permanent furniture. Since its completion, the facilities of its two upper floors have been used for national-defense projects. The building is of reinforced concrete, except for a few tile partitions, and is entirely fire-proof. The two upper floors are divided into numerous laboratories for various types of research and include a darkroom and an animal room. The basement includes a "tunnel," 15 feet wide by 9½ feet high, terminating in the cyclotron-room, 42 by 48 by 16 feet high with concrete roof-beams above the ceiling, covered with an 8-foot earth-fill for radiation shielding. The basement also contains a shop, stock-room, underground measuring room, cyclotron control-room, and rooms for heating and other equipment. The shop is equipped with a Browne and

Sharpe no. 1-A milling machine, four lathes (9-, 10-, 11-, and 13-inch), two drill-presses, metal band-saw, band cut-off saw, arbor-press, grinder, welding and brazing equipment, and numerous hand and precision tools.

The 200-ton Armco magnet was installed under the direction of J. N. Brown through courtesy of the Mosler Safe Company. The handling of the upper and lower members of the magnet (56 tons each) and of the other heavy castings offered unusual difficulties of transportation, especially within the city limits. The coils, weighing 13 tons each as manufactured by the General Electric Company, were assembled in the magnet along with the iron pole-pieces. The magnet, cast of Armco ingot by the American Rolling Mill Company, was machined within a tolerance of 0.003 inch for the parallelism of the pole-faces by the Mosler Safe Company. The 150-kw generator for the magnet, supplied by the General Electric Company, will excite the magnet to near saturation; the generator is shunt-wound and separately excited for close control of the magnet-current at almost any desired voltage within its rating.

The aluminum vacuum-chamber, in which the acceleration of particles is to be accomplished, was made by the Aluminum Company of America. It is 65 inches square and 17 inches high, with walls 1½ inches thick, welded together from the Aluminum Company's 61S alloy, and was precisely machined by that company. Five-inch Armco-iron lids are used on this vacuum-chamber in order to reduce the air-gap of the magnet and thus give a higher magnetic field than could be attained if nonmagnetic lids were used.

The radio-frequency system, associated with the vacuum-chamber, is housed in two 32-inch-diameter steel tanks which radiate from the vacuum-chamber and

terminate in a steel manifold to which the vacuum-pumps are attached. The front sections of the 32-inch tanks are in the stray field of the magnet and are made of stainless steel in order that they may be essentially nonmagnetic; the central sections and manifold are made of mild steel, the entire system weighing about 6000 pounds. These tanks serve also as pump-lines and are lined with copper to give a high electrical conductivity. In order to obtain efficient operation of this electrical system, it is necessary that great care be exercised in obtaining high conductivity by means of copper parts which cover all the steel pieces, the radio-frequency current being carried by the skin of this copper. To complete the concentric radio-frequency lines, steel tubes are threaded through the center of the 32-inch tanks and covered with copper casings which connect to the dees, or accelerating electrodes, supported at the ends of the steel tubes. The bottom and top of the vacuum-chamber are also covered with copper liners.

The dees are 53 inches in diameter; $\frac{1}{8}$ -inch copper was hammered into shallow saucers which were halved to make the D-shape. For evacuation of the entire system there are four special 8-inch, 3-stage, oil-diffusion pumps of the type developed in our laboratory from designs of the RCA Manufacturing Company. These pumps exhaust into a large Kinney mechanical pump having a displacement of 34 cubic feet per minute. Preliminary measurements on these pumps indicate that they have a speed of approximately 2000 liters per second, each, without a baffle. The four pumps with baffles should thus give a speed of about 4000 liters per second, which experience has indicated is quite adequate for the operation of a 60-inch cyclotron. Work is now in progress on testing of vacuum-parts for leaks. The

bronze target-box, installed in the side of the vacuum-chamber, is fitted with a vacuum-gate, which allows targets to be changed without relieving the vacuum of the main vacuum-system.

The control-desk, in which the operating controls of the cyclotron are all installed, is completed. A large steel box on the wall of the control-room contains operating and interlocking contactors and terminal strips from which the wiring radiates to the control-desk and through the main steel raceway to the power-room and cyclotron-room. The power-room, on the first floor with a large port through its floor into the tunnel below, contains the magnet motor-generator set and starter and low-voltage single-phase and three-phase power-transformers; small high-voltage power-supplies and the main rectifier will be installed in this room when completed. The steel cabinet is installed together with its contactors and a part of the wiring; the main raceway is partly completed for placing of some 40,000 feet of wire leads. The electrical circuits must be interlocked, so that controls may be operated in the proper sequence and apparatus may be protected against overloads, failure of the cooling system, and failure of various electrical supplies. This interlocking is accomplished by means of a number of contactors, relays, and various types of small switches and protective devices, together with the interlocking wiring. All operations and interlocks are indicated by small lamps on the control-desk. Power is supplied by the Potomac Electric Power Company through an underground transformer-vault just outside the building; circuits are for 400 kw of 440-volt, 3-phase power, and for 50 kw of 110-volt power. In emergency all power-circuits may be disconnected through any one of a number of push-buttons located near the cyclotron. Parts are on hand for construction

of the 200,000-volt rectifier used for the potential which draws the ions out of their circular path into the target-box, the 5-ampere, 1000-volt emission-supply for the arc ion-source, and the 200-kc, 4-kw radio-frequency supply used to light the filament which must run in a magnetic field; and parts are on order for the 225-kw rectifier which will power the final radio-frequency stage. Numerous small parts have been received, ordered, and made in our shop; these and the larger parts are being assembled and, barring further delays arising from the national emergency, and unforeseen difficulties, the cyclotron should be ready for active use early in 1942.

THEORETICAL-PHYSICS CONFERENCE

The topic of the Seventh Washington Conference on Theoretical Physics, May 22 to 24, 1941, under the joint auspices of the George Washington University and the Institution, was "The theory of elementary particles." Sixteen physicists representing eleven universities were invited to act as conveners of the conference. Besides these, eighteen guest-physicists took part, representing twelve universities, government departments, and private research organizations. The main subdivisions of the topics discussed at the conference were (1) elementary particles in cosmic rays, (2) elementary particles in nuclei, and (3) field-theory.

There were three general meetings. Dr. Fermi gave an evening lecture on "The elementary particles." Smaller groups of the Conference took part in several informal sessions.

Dr. Oppenheimer led the discussion on the theory of the meson. The meson has a charge which is equal to the charge of the electron, and its mass is intermediate between the masses of the electron and the proton. The meson is not present in the

cosmic radiation when it arrives at the Earth's atmosphere, but is created by some interaction between the original cosmic-ray particles and constituents of the atmosphere. The main problems discussed concerning the meson were the magnitude of its spin or angular momentum and the value of its magnetic moment. The evidence from the behavior of mesons in cosmic rays makes it highly probable that the value of the angular momentum is zero or one-half in the quantum units of angular moments. It was suggested that the meson may have angular momentum but that a change in sign would be connected with the reflections of a meson-wave function in space. This means mathematically that the meson is represented by a pseudo scalar rather than a scalar. This assumption has important bearing on the meson-theory of nuclear forces and on the theory of beta decay. It has been suspected for some time that mesons are created in large batches or showers. At the Conference it was suggested that mesons and nuclear particles interact strongly and that this strong interaction may account for the great number of mesons created simultaneously. The interesting part of this explanation is that in spite of the strong interaction there does not result a particularly strong scattering of the mesons by the nuclear particles.

Dr. Wigner was the leader of the discussion on the structure of more complex nuclei. These nuclei can absorb electromagnetic waves just as atoms do, but whereas atoms absorb ordinary or ultraviolet light, the radiation absorbed by nuclei is of much shorter wave-length and is called gamma radiation. This gamma radiation has unexpectedly small interaction with nuclei—much smaller than one would expect from the rough picture of an oscillating elementary charge which is confined in its motion to the small dimensions

(10^{-12} cm) of a nucleus. The possibility was discussed that this simple "dipole" interaction must be replaced by a "quadrupole" interaction arising from the oscillation of several charges whose main effects cancel one another. Another question concerned the decay possibility of the beta-active substances. Nuclei showing beta activity emit either an electron or a positron and in addition a neutrino. The decay probabilities in the beta activity depend on the assumptions about angular momenta and other properties that the two ejected particles possess at the moment of leaving the nucleus. It has been attempted to draw some conclusions about these properties from the empirical facts of the beta decay. The attempt was also made to find systematic relations between the composition of the nuclei and their beta decay. The beta decays in the series He^6 , B^{10} , C^{10} , C^{14} proved to be particularly difficult to understand. These nuclei consist of an even number of neutrons and an even number of protons. The number of neutron-pairs differs from the number of proton-pairs by +1 or -1. In spite of this similarity in structure, the beta-decay periods differ so strongly that it seems necessary to assign the He^6 and C^{10} decays to allowed transitions and to assume that the decays of B^{10} and C^{14} are strongly forbidden.

Dr. Weisskopf led a discussion on the nature of the forces represented by various fields which have been used both in classic physics and in modern theory. It was brought out at the Conference that even one of the oldest field-theories, the theory of electromagnetic fields, is open to serious revision when investigated in small regions of space, particularly when applied in the immediate neighborhood of elementary particles. A most radical suggestion put forward would abandon completely the concept of a field and would

reintroduce instead the idea of interaction of particles at a distance.

The question of artificial-meson production was discussed, and here there seems to be some hope of practical results as soon as it becomes possible to bombard nuclei with protons of about 100 million volts. It was found that even at such high bombardment-energies the influence of binding-energies within the nucleus remains important. Artificial production of mesons would probably help very greatly in understanding the nature of elementary particles and of nuclear forces.

COOPERATION IN NUCLEAR PHYSICS AT THE UNIVERSITY OF WISCONSIN AND THE GEORGE WASHINGTON UNIVERSITY

Professor G. Breit, of the University of Wisconsin, and Professor G. Gamow, of the George Washington University, continued as research associates and consultants. The results of investigations by them and their associates are summarized below [paragraphs (a) to (d) for Professor Breit and (e) to (h) for Professor Gamow].

(a) *Interpretation of nuclear resonances.* The theory of nuclear resonances has been systematized and the difficulties and inaccuracies in past treatments have been discussed. The method of complex characteristic values has been used to show that interference between levels affects both the numerator and the denominator of the formula for scattering cross-section. In this light the usual expansion for scattering cross-section as a sum of contributions having a resonance character appears unsuitable for a general understanding of the dependence of the cross-section on energy.

A generalization of the method of complex characteristic values to many dimensional problems has been made. The "radioactive state"—the state for which all

waves are outgoing—determines the characteristics of a scattering matrix. The form of the solution is a background matrix on which resonance is superposed. The radioactive state determines the damping constants of the resonance formulas and the phase-constants for displacement of the peaks. The most general form of the scattering matrix has been worked out for a system which can disintegrate in two independent ways. The determining conditions for the general form of the scattering matrix for a system with any finite number of modes of disintegration have been found.

In comparing nuclear-resonance theory with the optical analogue, both the method of complex characteristic values and that of the regular and irregular solutions have been used. It is found that the apparent position of gamma-ray emission and scattering levels is the same to a high degree of approximation for the case of a strong repulsive barrier. When such barriers are not present larger shifts may occur.

For certain problems not only in two but also in many dimensions, a method of construction and use of Green's function have been developed. In this way some idealized problems have been solved. A resonance model similar to the Gamow-Condon-Gurney radioactive-decay model has been worked out.

The examples show that quantitative applications with simplified damping constants and interference-type dispersion formulas have only a limited validity.

(b) *Proton-proton scattering.* The validity of phase-shift analysis independent of any assumed potentials makes a general formulation for the phase-shift problem important. A consideration of the conservation of momentum and the properties of the wave-function under rotation of the coordinate system as well as the many pos-

sible phase-shifts in the many-body problem are enumerated and classified.

In taking account of higher phase-shifts, a general rule for the first-order effects for any given L (orbital angular momentum) and various J 's (total angular momentum) has been worked out. The sum of the statistical weights multiplied by the phase-shifts replaces the L th phase-shift.

General order-of-magnitude considerations regarding the magnitude of relativistic effects show these to be on the limit of possible experimental detection. Such effects have been more fully investigated by L. E. Hoisington for a thesis at the University of Wisconsin. His results emphasize the fact that the range of forces in proton-proton scattering cannot be unambiguously determined.

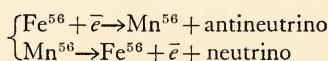
(c) *Proton-helium scattering.* Preliminary results of a phase-shift analysis indicate that in the p-anomaly the doublet is probably inverted and that higher states are detectable. This work was done by F. L. Friedman with some assistance from D. Bobroff.

(d) *Proton-hydrogen scattering.* The rectifier set originally constructed using a grant from the Carnegie Institution of Washington has proved valuable in supplying values for the scattering yield of protons in hydrogen in the range from 200 kev to 300 kev. This work was done by G. L. Ragan, W. R. Kanne, and R. F. Taschek. The observed scattering agrees nicely with expectation from the theoretical treatment of data at higher energies.

(e) *A theory of supernovae,* the vast stellar explosions studied extensively at the Mount Wilson Observatory during the past few years, was developed. The observational evidence concerning these stellar catastrophes, in which the luminosity of the star increases overnight by a factor of 10^9 , suggests that they are due to a sud-

den collapse of the entire stellar body accompanied by the liberation of tremendous amounts of gravitational potential energy. In fact, the most recent observations of the star remaining after the supernova explosion of A.D. 1054 show that it is now in the state of an extremely dense white dwarf, whereas the masses of gas ejected during the outburst form a luminous expanding shell known as the Crab Nebula.

It was indicated by Gamow that such a sudden collapse of a stellar body could be understood only if, at certain stages of its evolution, the star began to lose large amounts of its thermal energy from the central regions, in spite of the opacity of the material forming its body. Since all known kinds of radiation, including even the highly penetrating cosmic rays, would be completely absorbed in passing through the body of the star from the central regions to the surface, the only possibility of explaining the rapid cooling of the material in the interior lies in the assumption of neutrino-radiation, which has an estimated range of many light-years in lead. It can be shown that such neutrino-radiation must necessarily take place in the dense and hot interior regions of a contracting star. In fact, when the thermal energy of free electrons in a stellar interior approaches the value of beta-decay energy of some unstable element, the electrons will be captured by the corresponding nuclei with the ejection of an anti-neutrino, and then re-emitted in company with a neutrino. The typical example of such a process, called urca-process, that is, the process involving the unrecordable cooling agent, is given by the reaction of the most abundant iron isotope:



The repeated capture and re-emission of electrons by the nuclei will lead to the

continuous ejection (with creation) of neutrino-antineutrino pairs and will carry the energy in an unobservable way out into interstellar space. In the case of Fe⁵⁶, which forms about 10 per cent of stellar material, the energy-losses through the neutrino-emission will be as high as 10¹¹ erg/gm sec at the saturation point of 10¹⁰ °C.

(f) *Quantum-theory of beta decay.* In collaboration with Dr. Schenberg, of the University of São Paulo (Brazil), Gamow developed a number of formulas, based on the quantum-theory of beta decay, which permit calculation of energy-losses through neutrino-emission in terms of density and temperature of stellar material and the nuclear characterization of the element participating in the urca-process. Theoretical curves calculated for different elements abundant in stars indicate that urca-processes will begin at temperatures above 10⁸ °C (5 times central temperature of the Sun) with energy-losses between 10² and 10⁵ erg/gm sec for temperatures near 10¹¹ °C.

(g) Because of cooling of the interior regions of stars through neutrino-emission, the central pressure is bound to drop, and the outer layers, unsupported any more by gas-pressure, are bound to collapse inward. Such a collapse will be necessarily connected with the large gravitational energy-liberation in the outer layers of the star, which must cause the observed increase of luminosity and the blowing-out of the atmosphere. The dynamical equations which govern such a collapse-process can be easily written down, but their integration is mathematically very complicated. Attempts are now being made to perform numerical integration of these equations for some simplified models.

(h) Gamow was also working on the problem of the origin of chemical elements

at early stages of the expanding universe, when the mean density and mean temperatures of the matter in space were extremely high and all kinds of nuclear transformations may have taken place readily. Attempts have been made to extrapolate backward in time the present expansion of the universe, and to find the exact conditions of temperature and density at which the various nuclei have been formed. This involves the exact analysis of the cosmological equation of Einstein, and of the time-dependent solutions developed by Freedman and Lemaître. The result of this work, which is now in progress, must answer the interesting question as to whether the abundance of different elements which we now observe is due to equilibrium-conditions corresponding to a definite temperature and density, or whether, on the contrary, the nuclei originated from the primitive nuclear matter through some kind of irreversible fission process.

PUBLICATIONS

Publications bearing on nuclear physics are listed in the bibliography at the end of this report. Active part was taken by the staff in physics colloquia of the George Washington University, the Johns Hopkins University, and the Catholic University of America. Hafstad addressed the Engineering Club of Baltimore on "Atom smashing as it really is." Cowie (with L. A. Scheele, of the National Cancer Institute) addressed the New York Roentgen Society on "A survey of radiation protection in forty-five hospitals," and spoke on "Uses of artificial radioactivity in biology and medicine" at St. Elizabeth's Hospital. N. M. Smith, Jr., took part in the Chicago meeting of the American Physical Society, presenting a paper on "The absolute number of quanta in the bombardment of fluorine by protons." Breit gave a lecture on "Proton-proton scattering" at the University of Pennsylvania Bicentennial Conference, September 9, 1940.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The results of magnetic observations on land for the years 1927-1940 were in the course of preparation for publication by Vestine, J. W. Green, and Wallis. Final revision of the field-results was completed. Much of the material was made ready in manuscript form for publication in the series of Researches of the Department of Terrestrial Magnetism as "Land Magnetic Survey, Observations, 1927-1940."

Summaries of positions of stations and magnetic data for Africa, Australia, the Pacific Islands, South America, and Central America were prepared for various government and private organizations.

A preliminary study (see p. 63) was made of magnetic measurements obtained by McNish and J. W. Green in two local surveys near the volcano Santa María in Guatemala, on expeditions headed by Zies, of the Geophysical Laboratory.

The arrangement of material for constructing world isoporic charts of secular change for the epoch 1930-1935 was begun. Because of many observations during the International Polar Year 1932-1933, it should be possible to effect some improvement on Fisk's results for polar regions derived for the epoch 1920-1925. Preparations are being made for an analysis of

the Earth's field by spherical harmonics and other methods. The most formidable difficulty, which is of some serious consequence in these undertakings, results from the lack of magnetic observations over the oceans since the loss of the *Carnegie* in 1929. There appears but little hope that present observations on land can satisfactorily bridge the gap in observation over the oceans, which cover the major portion of the Earth's surface, although this remains a theoretical possibility. This is being investigated, however, as well as the feasibility of making observations with the aid of ships which are magnetic.

Good results were obtained with a method for correcting field-observations to mean of year, except in the region near the auroral zone, employing results of a world-wide network of observatories. The corrections found necessary for the Department's observations are sometimes as great as $50Y$ ($Y=0.00001$ CGS unit) in H for the effect of post-perturbation alone, and if neglected may seriously affect estimates of secular change. A study of methods for the reduction of field-observations to mean of day, on a world-wide scale, is also nearing completion. A project involving the reduction of all the results of the Department to several suitable mean epochs is under consideration.

The Department has cooperated through the loan of field-instruments to the Apia, Hermanus (Cape Town), Cheltenham, Christchurch, and Mauritius observatories, and to the Government of South Australia, the British East African Meteorological Service, the Aerial, Geological, and Geophysical Survey of Northern Australia, the United States Antarctic Service, and the Louise A. Boyd Arctic Expedition of 1941. International magnetic standards of the Department were continued in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Ob-

servatory, where CIW sine-galvanometer 1 and CIW Schulze earth-inductor 48 are the standards for horizontal intensity and inclination. Corrections for field-instruments were maintained, in cooperation with the United States Coast and Geodetic Survey, through comparisons with the international magnetic standard of the Department at the Cheltenham Magnetic Observatory.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Director Walter of the British East African Meteorological Service, using CIW magnetometer-inductor 13, continued cooperative work. He occupied 24 stations, during September 1940 to March 1941, in British East Africa, as follows: Mombasa, Dar es Salaam, Nairobi, Kisumu, Kitale, and Equator in Kenya and Tanganyika; and Hoima, Butiaba, Moyo, Arua, Gulu, Kitgum, Lira, Soroti, Tororo, Jinja, Masaka, Mbarara, Kabale, Kichwamba, Fort Portal, Mubende, Kampala, and Busia in Uganda. On the basis of these and previous CIW data, a provisional isogonic chart of Uganda Protectorate for epoch February 1941 was prepared.

Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, maintained control of secular variation at the Hermanus (Cape Town) Observatory, using CIW magnetometer-inductor 17 as standard. Dr. Ogg has in preparation new isogonic and secular-variation charts of the African continent, which are based largely on values resulting from the work of the Department in Africa and for which he was supplied all CIW data to date.

The Aerial, Geological, and Geophysical Survey of Northern Australia has reported on its cooperative magnetic survey during the years 1939-1940. The primary object has been to reoccupy stations to obtain data concerning secular variation, L. A. Richardson, of that Survey, using CIW magnetometer-inductor 18. As indicated in previous reports, control on the constants of magnetometer-

inductor 18 was obtained by comparisons with Parkinson, using CIW magnetometer-inductor 28, in 1937 at Sydney and again with the standards at the Watheroo Magnetic Observatory in 1940. On a trip from Blair Athol, Queensland, to The Granites, Northern Territory, the stations Clermont, Jericho, Winton, Cloncurry A, and Camooweal were occupied in 1939, and Lolworth and Croydon in Queensland in 1940. Other stations included Tennant's Creek, Rockhampton Downs, The Granites and The Granites Road no. 1 and Road no. 2, Thomson's Rockhole, and Conistan in 1939, and Redbank in 1940, in Northern Territory. The station Blacktown B, in New South Wales, was also occupied. Of these all but 8 were reoccupations. Six reoccupations of Blacktown have been made since 1937, and these, together with an approximate connection to Red Hill, permit the secular-variation curves for Sydney to be brought roughly up to date.

The Department of Scientific and Industrial Research of New Zealand made extensive intercomparisons with CIW magnetometer-inductor 27 at Amberley (Christchurch) Observatory, and Director H. F. Baird planned its use in a resurvey of New Zealand. The plan is to observe at about 12 secular-variation CIW and new stations through the length of the country, commencing from the extreme south. This backbone having been established, the survey will be extended on both sides according to the season. By the end of

April 1941, 4 stations in the southern part of South Island had been occupied, including a reoccupation of the CIW station at Roxburgh. The illness of Director Baird interrupted the program, which, according to latest advices, is again under way.

Louise A. Boyd Arctic Expedition, 1941. Arrangements were completed for cooperation with Miss Louise A. Boyd's Arctic Expedition of 1941 on Captain Bartlett's schooner *Effie M. Morrissey*, which left Washington June 11, 1941. CIW magnetometer-inductor 16 was altered by lengthening its deflection-bar so that determinations of magnetic horizontal intensity could be measured for values as low as 0.02 CGS unit, and CIW Dover dip-circle 222 was provided for observation at stations where H is less than 0.02 CGS unit and as low as 0.005 CGS unit, using a specially adapted method of observation in two places at right-angles. Thus the equipment is suitable for determining the magnetic elements up to 90° geomagnetic latitude. Descriptions and sketches of CIW stations in Canada, Greenland, and Labrador were supplied. Training in the methods of observation and of computation for magnetic and geographic determinations was given by Johnston, Scott, and J. W. Green to F. R. Gracely, of the staff of the National Bureau of Standards, who accompanied the Expedition—particular emphasis being placed on unusual and difficult geomagnetic conditions prevailing in high latitudes.

OBSERVATORY-WORK

Johnston continued in charge of the Section of Observatory-Work. The reductions of magnetic data and computations concerned with the analysis of the magnetic results from the observatories were continued with the assistance of Scott and Miss Balsam. McNish was engaged on national-defense investigations, but found time for discussion of the magnetic observations in Guatemala. Wait and Torreson continued analyses and investigations of the atmospheric-electric and meteorologi-

cal data from Watheroo and Huancayo for the 11-year period 1924–1934, already tabulated for offset publication by Miss Balsam and Hendrix. Monthly and annual tables of air-conductivity (positive and negative), atmospheric potential-gradient, and air-earth currents were prepared and harmonic analyses were made of the potential-gradient tabulations.

The complete geomagnetic program was continued at the Watheroo and Huancayo observatories. In addition, at Watheroo,

in cooperation with the Australian Commonwealth Department of Air, weekly summaries of ionospheric data, forecasts of conditions likely to affect short-wave radio transmission, and predicted values of maximum usable frequencies for various distances were prepared. The geomagnetic program at both observatories comprises continuous records of the three magnetic elements (D , H , and Z), positive and negative conductivity of the air, atmospheric potential-gradient at the surface,

all days during 1939 and the preliminary values for 1940 are shown in table I.

To assist researchers in ionospheric and geomagnetic fields, both our observatories continued assigning 3-hour-range indices K . These indices have proved to be an excellent measure of geomagnetic activity due to corpuscular radiation, and range from 0 (very quiet) to 9 (extremely disturbed). Radio communication is affected when the index is 5, and there is a nearly complete block-out of communication for

TABLE I
ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGrams FOR ALL DAYS, 1939 AND 1940

YEAR	DECLINA-TION, D	INCLINA-TION, I	INTENSITY-COMPONENTS					LOCAL MAGNETIC CON- STANT, G
			Horizontal, H (γ)	Total, F (γ)	North-south, X (γ)	East-west, Y (γ)	Vertical, Z (γ)	
WATHEROO MAGNETIC OBSERVATORY								
1939.....	3° 21'0 W	64° 23'7 S	24687	57127	24645	-1442	-51517	35678
1940.....	3 15.8 W	64 24.3 S	24700	57175	24659	-1406	-51564	35704
HUANCAYO MAGNETIC OBSERVATORY								
1939.....	7 00.4 E	2 15.1 N	29554	29577	29333	3605	1162	29560
1940.....	6 55.9 E	2 14.3 N	29517	29540	29302	3562	1154	29523

earth-currents in two directions at right-angles with duplicate lines, heights of the ionosphere by fixed and automatic multi-frequency, daily spectrohelioscopic observations during the periods assigned by the International Astronomical Union, and the meteorological elements. In addition, a three-component seismograph and precision cosmic-ray meter are operated at Huancayo.

The Section continued the reduction of the magnetic data from the Watheroo and Huancayo observatories. Final reductions were made for the year 1939 and preliminary compilations for the year 1940. The final values of the magnetic elements for

an index of 9. K -indices for the 7-day period ending Greenwich midnight on Friday are regularly transmitted to the Washington office, where also similar reports are received from the five magnetic observatories of the United States Coast and Geodetic Survey. The indices are normalized to represent world-wide geomagnetic activity, and an average index is obtained for each 3-hour period of the Greenwich day. Individual indices from each of the seven American-operated observatories and the mean index are published weekly in *Science Service Research Aid Announcement of Cosmic Data*. K -indices are also published quarterly in

the Journal of Terrestrial Magnetism and Atmospheric Electricity.

During the report-year, *K*-indices were extended to cover the period 1937-1940. With the cooperation of Captain N. H. Heck, of the United States Coast and Geodetic Survey, and Dr. J. Bartels, Director of the Geophysikalischs Institut at Potsdam, Germany, indices were assigned for Sitka (Alaska), Niemegk (Germany), Cheltenham (Maryland, United States), Huancayo (Peru), and Watheroo (Western Australia) for the year 1937. They were also assigned for these five observatories and Tucson (Arizona, United States) and San Juan (Puerto Rico) for the second half of 1938, the year 1939, and the period January 1 to April 6, 1940, at which date *K*-indices were first assigned for URSI broadcasts.

The *K*-indices were assembled by the Section and transformed into reduced indices, *K_r*. The reduced indices were averaged, double weight being given to those from Sitka, Niemegk, Cheltenham, and Watheroo, to form mean *K*-indices, *K_w*, which represent normalized world-wide geomagnetic activity for each 3-hour period of the Greenwich day. Daily indices, *B*, were computed from the eight average indices for each day, due allowance being made for the *actual* ranges experienced, since the ranges in gammas for the *K*-indices are nonlinear. Mean *K*-indices were then presented graphically by 27-day periods beginning with January 1, 1937, the first day of solar rotation no. 1420, and ending with January 24, 1941, the last day of solar rotation no. 1474.

The Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics passed a resolution at its Seventh Assembly, held in Washington in September 1939, inviting all magnetic observatories during the period 1940 to 1942 to assign *K*-indices.

Despite international disturbances, *K*-indices have been supplied by twelve observatories, namely (in order of geomagnetic latitude), Sodankylä, Lerwick, Dombås, Meanook, Eskdalemuir, Rude Skov, Agincourt, Witteveen, Abinger, San Fernando, Zô-Sè, and Cape Town (Hermanus). The indices for Godhavn, Pilar, Toolangi, and Christchurch are in course of preparation, and those for Slutzk have appeared in the *Cosmical Data Review of the USSR*. The *K*-indices for the first half of 1940 for twelve magnetic observatories, other than the American-operated seven, were tabulated and published in the June 1941 issue of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*.

The magnetic and atmospheric-electric programs of the Department were assisted by various magnetic observatories. Our international magnetic standards were maintained at the Cheltenham Magnetic Observatory and our program of observations of atmospheric conductivity (positive and negative), air potential-gradient, and earth-currents was continued at Tucson Magnetic Observatory; both of these observatories are operated by the United States Coast and Geodetic Survey. The observations of atmospheric potential-gradient were continued at Apia Observatory, Western Samoa, by the Department of Scientific and Industrial Research of New Zealand until 1941, when it was deemed the series had continued over a sufficiently long period for the purpose desired.

OPERATIONS AT OBSERVATORIES

Watheroo Magnetic Observatory, Watheroo, Western Australia. The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1$ south and longitude $115^{\circ} 52' 6$ east, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Weekly determinations

of base-line values were made by observations with magnetometer and earth-inductor in the absolute observatory. Monthly determinations of scale-value of the horizontal-intensity variometer were made by the method of magnetic deflection; vertical-intensity scale-values were determined daily by the electrical method.

The la Cour rapid-run magnetograph was also in continuous operation. Some adjustments to the optical system were found necessary from time to time. Scale-value determi-

determinations for the Eschenhagen and la Cour variometers.

The preliminary mean values of the magnetic elements for all days of 1940, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $-3^{\circ} 15' 8''$; horizontal intensity, 0.24700 CGS unit; vertical intensity, -0.51564 CGS unit; and inclination, $-64^{\circ} 24' 3''$. The preliminary values for the annual changes in the magnetic elements during 1939.5 to 1940.5 are: declination, $+5' 2''$; horizontal intensity, $+13$ gammas; vertical intensity, -47 gammas; inclination, $-0' 6''$.

Magnetic data were supplied, on request, to the Australian Department of Defence and the Western Australian Government Astronomer.

Earth-potentials over a system of electrodes, as described in previous reports, were recorded, and the monthly mean curves of diurnal variation show consistent results. Tests of line-insulation and electrode-resistance were made regularly.

The program of atmospheric-electric observations, involving the continuous recording of air-potentials and positive and negative air-conductivity, was maintained. As is usual, certain days were excluded from the tabulations owing to adverse conditions of weather or the presence of smoke from bushfires. Observations for the reduction of values as recorded, to those obtaining at a point 1 meter above a plane surface, were made quarterly. Preliminary mean values of the atmospheric-electric elements are shown in table 3.

The automatic multifrequency ionospheric recording apparatus functioned practically continuously, with brief interruptions caused by necessary maintenance, control-observations, adjustments, and minor repairs. Scalings and reduction of the records were kept current. Quarterly reports on ionospheric conditions, accompanied by data and graphs, were prepared for publication in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. Tables 4 and 5 show the mean

TABLE 2

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO
MAGNETIC OBSERVATORY, 1940

MONTH	SCALE-VALUES IN γ/MM			
	ESCHENHAGEN		LA COUR	
	H (reduced to base- line)	Z (means of daily values)	H	Z
January.....	2.35	3.39	4.44	2.92
February.....	2.37	3.39	4.43	2.80
March.....	2.38	3.31	4.43	2.78
April.....	2.37	3.37	4.47	2.93
May.....	2.39	3.35	4.51	3.09
June.....	2.39	3.39	4.57	3.35
July.....	2.39	3.49	4.57	3.42
August.....	2.38	3.51	4.54	3.18
September....	2.39	3.38; 3.21	4.60	3.07
October.....	2.38	3.22	4.44	2.94
November....	2.36	3.30	4.57	2.94
December....	2.38	3.31	4.48	2.79

nations, by the electrical method, were made monthly.

Tests of orientation of the magnets of the variometers (made necessary every few years by the gradual change of the magnetic meridian) were made during July 1940. Three-hour-range indices, K , were assigned from examination of the Eschenhagen magnetograms and transmitted weekly to Washington. Until the end of January 1941 the data were sent through the American Consul in Perth, and after that by radio through the Australian Commonwealth Department of Air. Table 2 gives the monthly scale-value

TABLE 3

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
WATHEROO MAGNETIC OBSERVATORY, 1940

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction-factor	Value (v/m)	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	17	....	102.1	1.63	1.46	3.09	1.12
February.....	10	1.10	115.0	1.43	1.25	2.68	1.14
March.....	19	....	131.2	1.28	1.01	2.29	1.27
April.....	24	1.13	100.4	1.82	1.41	3.23	1.29
May.....	20	....	75.9	2.28	2.10	4.38	1.09
June.....	18	....	68.3	2.39	2.14	4.53	1.12
July.....	18	....	75.2	2.38	1.98	4.36	1.21
August.....	19	1.20	84.4	2.12	1.87	3.99	1.13
September.....	18	....	83.5	2.04	1.78	3.82	1.15
October.....	21	....	89.2	1.78	1.54	3.32	1.16
November.....	21	1.16	96.0	1.83	1.79	3.62	1.02
December.....	15	....	110.5	1.69	1.44	3.13	1.17
Totals and means...	220	1.15	94.3	1.89	1.65	3.54	1.10

TABLE 4

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,
WATHEROO MAGNETIC OBSERVATORY, 1940

120° east meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
00.....	...	...	347	266	....	....	4.81	....
01.....	...	...	342	260	....	....	4.63	....
02.....	...	...	338	260	....	....	4.39	....
03.....	...	...	337	258	....	....	4.18	....
04.....	...	...	335	256	....	....	3.94	....
05.....	...	...	331	261	0.94	....	3.78	....
06.....	264	252	305	253	1.47	3.46	4.23	0.55
07.....	247	236	294	261	2.24	3.96	5.80	0.65
08.....	235	224	299	278	2.81	4.08	7.06	0.76
09.....	232	223	310	289	3.16	4.51	7.80	0.80
10.....	227	216	322	297	3.35	4.77	8.30	0.84
11.....	226	214	330	301	3.48	4.94	8.67	0.86
12.....	225	214	334	307	3.52	4.96	8.87	0.88
13.....	230	219	332	305	3.47	4.94	9.05	0.88
14.....	233	221	332	299	3.40	4.82	9.14	0.86
15.....	235	224	326	290	3.22	4.58	9.06	0.82
16.....	237	228	317	274	2.91	4.25	8.74	0.76
17.....	245	235	309	256	2.37	3.80	8.32	0.70
18.....	257	242	305	238	1.68	3.51	7.50	0.60
19.....	...	...	313	235	1.13	....	6.57	0.54
20.....	...	...	326	240	....	....	5.81	....
21.....	...	...	339	254	....	....	5.30	....
22.....	...	...	350	262	....	....	5.03	....
23.....	...	...	354	268	....	....	4.91	....

hourly values and monthly means of ionospheric data for the year 1940.

After some negotiation, arrangements were made for supplying, by telephone to the Australian Commonwealth Department of Air, weekly summaries of ionospheric data, forecasts of conditions likely to affect short-wave radio transmission, predicted values of maximum usable frequencies for various distances, etc. This cooperative work began January 1, 1941, the preparation of the data being done by W. D. Parkinson, who was appointed temporary part-time observer,

tions were transmitted monthly to Washington.

The usual meteorological program, as described in previous reports, was carried out; meteorological data were supplied monthly to the Commonwealth Weather Bureau as in previous years. Table 6 shows the monthly rainfall at Watheroo during 1940.

The arrears of scalings and reduction which existed at the beginning of this report-year were cleared off by the end of 1940, and the work has been kept current since then.

TABLE 5
PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,
WATHEROO MAGNETIC OBSERVATORY, 1940

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
January.....	225	212	347	295	3.36	4.86	6.46	0.83
February.....	220	211	337	287	3.25	4.85	6.38	0.75
March.....	227	224	336	274	3.15	4.83	7.01	0.84
April.....	231	220	320	257	2.95	4.66	7.43	0.75
May.....	231	225	298	245	2.78	4.38	5.96	0.74
June.....	235	225	295	248	2.75	4.15	5.36	0.74
July.....	228	220	294	247	2.75	4.25	5.35	0.68
August.....	230	220	309	255	3.01	4.61	5.94	0.78
September....	231	217	327	258	3.13	4.89	6.95	0.80
October.....	235	219	343	277	3.22	5.01	7.10	0.80
November....	239	225	354	295	3.28	5.05	7.37	0.85
December....	232	224	354	307	3.34	4.84	6.65	0.82
Mean.....	230	220	326	270	3.09	4.70	6.50	0.78

under Australian Air Force (Civil Staff) regulations, and who is using the facilities of the Observatory in connection with this appointment. Ionospheric data were also supplied, on request, to the Radio Research Board of the Commonwealth Council for Scientific and Industrial Research, the Chief Radio Inspector of the Postmaster-General's Department, and the (United States) National Bureau of Standards. Radio inspectors of the Postmaster-General's Department visited the Observatory August 13, 1940.

Visual observations of solar activity were made on all possible days with the Hale spectrohelioscope, and reports of the observa-

The shock of an earthquake, the epicenter of which was probably in the Indian Ocean, close to the coast of Western Australia, was felt at the Observatory on April 29, 1941; the earth-movement was sufficiently severe to break the fiber of the positive conductivity electrometer and permanently to displace the horizontal-intensity magnet of the la Cour variometer.

Considerable work was done to improve the storage and supply of water. The supply of prompt reports on ionospheric conditions to the Department of Air rendered the daily development of the ionospheric traces imperative, and the water-supply for this was

obtained from the deep bore put down in 1937. In order to obtain catchment from the large roof of the variation-observatory, it was reroofed, painted with aluminum paint, and fitted with nonmagnetic piping to take the rain-water to the main storage-tank. Additional storage-tanks were installed at various buildings to conserve the water from winter rains. The road from the Observatory toward Watheroo was improved by the Moora Road Board and its surface kept reasonably good by the use of a light drag. The installation of the underground wiring, begun last year,

TABLE 6
RAINFALL AT WATHEROO MAGNETIC OBSERVATORY
DURING 1940

Month	Monthly total (in.)	No. days	Average for 23 years (in.)
January.....	0.30	8	0.35
February.....	0.02	1	0.54
March.....	0.07	2	1.09
April.....	0.05	2	0.88
May.....	1.90	8	2.16
June.....	2.09	12	3.38
July.....	2.66	13	3.00
August.....	0.98	9	2.24
September....	1.19	7	1.26
October.....	1.30	8	0.85
November....	0.12	3	0.31
December....	1.02	5	0.38
Totals.....	11.70	78	16.44

was continued despite some delay occasioned by the difficulty of obtaining supplies. As might be expected, the work of the Observatory was adversely affected in many ways by world conditions, and it is therefore all the more gratifying to be able to acknowledge the sympathetic good-will and assistance of various government departments and individuals. The Department of Trade and Customs continued to allow free entry of essential supplies and equipment, the Department of Air cooperated in the handling of radio messages between the Observatory and Washington, and the continuation of the ionospheric program has been facilitated by the good-

will and assistance of the Postmaster-General's Department.

Considerable assistance was given to the Observatory by C. H. Derry, American Consul in Perth, and his staff, by cabling weekly messages of magnetic character to Washington through the United States Department of State when the Observatory itself was unable to radio the messages owing to war conditions.

Parkinson continued as Observer-in-Charge; Prior resigned on September 25, 1940, to take an appointment under the Radio Research Board, and was replaced November 20, 1940, by L. N. D. Lucas. McCarthy and Muhling continued as junior observers and George and McCall as mechanic and assistant mechanic, respectively; a general hand was also employed. Grateful acknowledgment is made of the continued efficiency and zeal of all the staff in completing a successful year's work under difficult conditions.

Huancayo Magnetic Observatory. The Huancayo Magnetic Observatory is situated nearly 9 miles about west of Huancayo in the central valley of the Peruvian Cordillera, in latitude $12^{\circ} 02'7$ south and longitude $75^{\circ} 20'4$ west, at an altitude of 3350 meters (11,000 feet) above sea-level.

Practically all the Observatory's work is done by the use of automatically recording apparatus, most of which record photographically. Except for the ionospheric recorder and the meteorological recorders, all instruments record intervals of Greenwich days, since traces are changed at $19^{\text{h}} 75^{\circ}$ west meridian time. Photographic traces are developed daily for better control of instrumental equipment.

The magnetographs consist of two separate three-variometer units: an Eschenhagen and a rapid-run la Cour, which operated continuously during the year. Weekly absolute observations were made with magnetometer and earth-inductor for the control of baselines. Scale-value determinations for the horizontal-intensity and vertical-intensity variometers of the la Cour magnetograph

were made on or near the fifteenth of each month by the Helmholtz-coil method. For the Eschenhagen magnetograph, Helmholtz-coil scale-value determinations were made once each week for the *H*- and *D*-variometers and three times each week for the *Z*-variometer. The low-sensitivity la Cour *H*-variometer recorded on the Eschenhagen magnetogram.

Air-potentials were recorded continuously with the standard potential-gradient apparatus. Scale-values were determined once every two weeks and reduction-factors quarterly by comparison with potentials measured on the standardization-plot near by. Positive and negative conductivity of the air were recorded continuously and scale-value observations made every two weeks.

Earth-current potentials were recorded on the Leeds and Northrup recording potentiometer for two separate systems of north-south and east-west pairs of electrodes.

Daily seismograms were obtained from the two Wenner horizontal-component seismometers and the Benioff vertical-component seismometer. Analyses of all important seismic disturbances were made and forwarded with the monthly journal at the end of each month, and twenty-two of these were of sufficient importance to be sent in the international seismic code with the weekly broadcast of scientific data.

Cosmic-ray meter model C no. 2 recorded continuously with little loss of trace. Weekly checks of the electrical and mechanical zeros of the electrometer were made and also of the high-potential balance.

Observations of the Sun were made daily on the Hale spectrohelioscope as conditions of weather permitted, at the assigned observational periods from 15^h 30^m to 16^h 00^m and 16^h 30^m to 17^h 00^m GMT. Monthly reports were prepared and transmitted to Washington; only five times during the report-year was there seen sufficient activity to merit description.

The ionospheric equipment operated continuously for both the multifrequency and the fixed-frequency program, with breaks in the continuity only during the brief periods

required for maintenance and repairs or when difficulties with the power-system made operation impossible. The monthly calibrations and regular daily check on operation of the equipment were maintained. Scaling and tabulation of values were kept practically current and at present are being completed within a few days of the close of each month for immediate transmittal to Washington by air. Quarterly reports were prepared during the year and with their compilations of data and graphs were regularly published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*.

Electric power for the Observatory was supplied by the 6-kw Diesel direct-current generator. During two periods of over 15 days, when the Diesel was under repair, power was supplied by the two stand-by Kohler units. The voltage-controller on the Diesel direct-current generator functioned satisfactorily, as did also the two converters which provide alternating current for the ionospheric equipment, even though they were run continuously at full capacity or more.

Daily morning meteorological observations were continued as in previous years, as was also the operation of the recording instruments in the meteorological shelter and those used in conjunction with the atmospheric-electric and cosmic-ray studies. Determinations of condensation-nuclei were made daily with the Aitken nuclei-counter. The minimum temperature for the year was -10°o C and the total rainfall between July 1, 1940 and June 30, 1941 was 33.81 inches—much greater than the average of 28.75 inches for the previous 19 years. Tabulations of meteorological data were supplied monthly to the Servicio Meteorológico Nacional del Perú, to the Centro Geográfico Departamental de Junín, and to several interested persons.

All tabulations of data, original traces from all instruments, and complete journals of instrumental operation and control are forwarded to Washington as soon as the work on them is completed at the Observatory.

The preliminary mean values of the magnetic elements for all days of 1940, as de-

duced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $+6^{\circ} 55' 9''$; horizontal intensity, 0.29517 CGS unit; vertical intensity, 0.01154 CGS unit; inclination, $+2^{\circ} 14' 3''$. The preliminary values for the annual changes in the magnetic elements during 1939.5 to 1940.5 are: declination, $-4.5'$; horizontal intensity, -37 gammas; vertical intensity, -8 gammas; inclination, $-0.8'$.

Preliminary monthly mean values of the

The Observatory continued to enjoy the confidence and friendship of local Peruvians of all classes. The American Ambassador to Peru and his family and Sra. Prado, wife of the President of Peru, were distinguished visitors. The United States Embassy continued to use its good offices in obtaining free entry for equipment and supplies for the Observatory, and the United States Consulate extended assistance in many ways. As in past years, the work has been cordially supported by the interest of the Peruvian Government and its officers.

TABLE 7

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
HUANCAYO MAGNETIC OBSERVATORY, 1940

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction-factor	Value (v/m)	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	3	....	53.0	3.98	3.97	7.95	1.00
February.....	4	1.19	50.0	3.88	4.02	7.90	0.97
March.....	4	....	57.4	3.85	3.94	7.79	0.98
April.....	7	....	57.9	3.33	3.21	6.54	1.04
May.....	13	1.20	53.4	3.29	3.45	6.74	0.93
June.....	12	....	47.8	3.68	4.07	7.75	0.90
July.....	16	....	54.5	3.21	3.40	6.61	0.94
August.....	12	....	49.6	4.08	4.43	8.51	0.92
September.....	6	1.18	46.4	4.41	4.33	8.74	1.02
October.....	6	....	43.7	4.62	4.87	9.49	0.95
November.....	5	....	48.0	4.32	4.80	9.12	0.90
December.....	3	....	44.4	4.78	5.20	9.98	0.92
Totals and means...	91	1.19	50.5	3.95	4.14	8.09	0.96

atmospheric-electric results for the year 1940 are given in table 7.

Mean hourly values of ionospheric data and their monthly means for 1940 are listed in tables 8 and 9.

The Observatory property was duly maintained, improvements in electric wiring in the buildings were made and are to be extended, and careful attention was given to the provision of suitable fire-extinguishing equipment. The water-supply has been sufficient, though critically low several times during the year. The road to Huancayo was much improved.

H. W. Wells continued as Observer-in-Charge until November 1, 1940, when he returned to duty at Washington. He was replaced by P. G. Ledig, who arrived early in October. On the scientific staff during the year were W. Culmsee, who resigned late in September 1940 to join the British forces; R. C. Coile; and M. W. Jones, who arrived at the Observatory late in December 1940. T. Astete, A. Macha, and V. Murga, who continued as clerical assistants, also gave valuable assistance in the reduction of data and general operation of the Observatory. The hearty cooperation of all members of the

TABLE 8
PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,
HUANCAYO MAGNETIC OBSERVATORY, 1940

west meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
00.....	...	...	322	249	...	...	7.59	....
01.....	...	...	316	248	...	...	6.87	....
02.....	...	...	314	253	...	...	6.10	....
03.....	...	...	311	256	...	...	5.36	....
04.....	...	...	306	258	...	...	4.70	....
05.....	...	...	308	260	0.87	...	4.23	0.67
06.....	...	...	320	266	1.69	...	5.79	0.73
07.....	...	...	321	246	2.55	...	8.39	0.92
08.....	245	229	363	282	3.07	4.77	9.93	1.15
09.....	235	221	415	301	3.51	5.00	10.46	1.48
10.....	224	216	451	318	3.77	5.13	10.33	1.74
11.....	218	213	463	332	3.91	5.16	10.00	1.86
12.....	215	211	463	347	3.94	5.16	9.85	1.89
13.....	214	209	462	333	3.87	5.09	9.93	1.82
14.....	217	210	465	323	3.73	4.97	10.08	1.72
15.....	226	213	461	304	3.43	4.75	10.24	1.49
16.....	247	221	459	293	2.96	4.57	10.31	1.15
17.....	...	...	451	255	2.38	...	10.24	0.93
18.....	...	...	447	284	1.38	...	10.03	0.76
19.....	...	...	469	320	0.85	...	9.37	0.68
20.....	...	...	451	307	...	...	8.94	....
21.....	...	...	409	286	...	...	8.76	....
22.....	...	...	368	266	...	...	8.46	....
23.....	...	...	341	257	...	...	8.02	....

TABLE 9
PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,
HUANCAYO MAGNETIC OBSERVATORY, 1940

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
January.....	222	214	414	308	2.87	4.88	8.36	1.19
February.....	214	208	395	277	2.87	4.93	9.15	1.33
March.....	218	209	384	264	2.88	5.03	9.37	1.46
April.....	219	209	371	259	2.72	4.99	8.97	1.32
May.....	221	207	354	264	2.55	4.83	7.59	1.09
June.....	221	207	357	273	2.53	4.81	7.07	1.01
July.....	218	205	363	273	2.56	4.84	7.11	1.11
August.....	227	216	394	289	2.74	4.91	7.55	1.37
September.....	233	226	408	284	2.83	4.91	8.73	1.39
October.....	239	231	421	290	2.94	5.01	10.07	1.35
November....	240	230	427	298	2.99	5.04	9.35	1.32
December....	251	228	439	337	3.00	5.24	8.71	1.25
Means.....	227	216	394	285	2.79	4.95	8.51	1.27

staff made possible the successful though difficult geophysical program.

COOPERATION WITH OTHER OBSERVATORIES

Cheltenham Magnetic Observatory, United States. The cooperative program with this observatory of the United States Coast and Geodetic Survey was continued. CIW instruments on loan to the Observatory served to control standards in the horizontal and

magnetism and atmospheric electricity. This observatory also undertakes observations in other fields of geophysics, including meteorology and seismology.

CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations of declination, horizontal intensity, and inclination. Eschenhagen variometers and a Godhavn balance were used to obtain continuous photographic records of declina-

TABLE 10

POTENTIAL-GRADIENT AND METEOROLOGICAL SUMMARY, APIA OBSERVATORY, 1940

MONTH	POTENTIAL-GRADIENT		METEOROLOGICAL ELEMENTS					
	No. zero-days	Value (v/m)	Pressure (mb)	Temp. (°F)	Rainfall (in.)	Rel. hum. 9 A.M. (per cent)	Sunshine (hrs.)	Wind velocity (miles/hr.)
January.....	8*	112	1008.0	80.8	3.32	75	232.7	4.9
February.....	6	125	1007.9	81.0	12.93	76	215.3	5.6
March.....	4	124	1008.5	80.9	14.56	81	234.3	4.7
April.....	5	117	1009.7	80.6	8.14	82	200.4	4.3
May.....	18	125	1010.1	80.4	5.07	78	248.3	6.4
June.....	12†	128	1010.6	79.6	7.25	81	186.8	8.5
July.....	27	134	1012.0	77.2	1.79	76	220.0	7.3
August.....	17	135	1010.8	78.5	3.34	78	252.9	7.7
September.....	8	112	1011.3	79.2	3.83	74	174.5	10.0
October.....	7	126	1011.2	79.3	6.80	77	202.1	6.5
November.....	10	131	1009.6	79.7	3.57	74	222.6	8.2
December.....	8	141	1006.1	80.1	7.81	78	177.7	6.3
Totals and means..	130	126	1009.7	79.8	78.41	77	2567.6	6.7

* Eight days of character 0 occurred in January, but only 7 were used in computing means.

† Twelve days of character 0 occurred in June, but only 11 were used in computing means.

vertical components of geomagnetic intensity. The cosmic-ray records with the CIW model C precision meter were continued. The necessary controls in constants and corrections on standards for CIW instruments used in the field were obtained with the generous cooperation of Observer-in-Charge Ludy, G. Hartnell (who retired March 31, 1941), and other members of the Observatory's staff.

Apia Observatory, Western Samoa. The Department continued cooperation with this observatory, through its Acting Director H. B. Sapsford and staff, in the program in geo-

tion, horizontal intensity, and vertical intensity.

Atmospheric potential-gradient was measured with a Benndorf electrometer. The leak-free potentiometric method of Gish and Sherman was used to determine the reduction-factor of the Land Station, and results showed that its value is still 1.00. During 1940, 130 days of zero-character were recorded, with a mean value of 126 volts per meter. The monthly number of zero-days and average potential-gradients are shown in table 10. The annual average hourly values in volts

per meter based on the monthly means are as follows: 96, 98, 95, 91, 98, 105, 144, 230, 243, 167, 128, 116, 106, 102, 99, 95, 95, 100, 124, 176, 168, 135, 111, and 99.

Tucson Magnetic Observatory, United States. The Department's equipment for recording atmospheric potential-gradient, positive and negative air-conductivities, and earth-currents, through the cooperation of the United States Coast and Geodetic Survey, was efficiently operated and controlled by Observer-in-Charge Roland F. White to April

from the Cape Town Observatory to a new site at Hermanus, because of electric-railway disturbances at the Cape Town site, was effective January 1, 1941.

Royal Alfred Observatory, Mauritius, Indian Ocean. The loan of CIW marine-inductor 4 was continued for the control of the vertical-intensity records.

College, Alaska. The necessary directions for the establishment of a magnetic observatory at College, Alaska, in cooperation with the University of Alaska, in connection with

TABLE II
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
TUCSON MAGNETIC OBSERVATORY, 1940

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction-factor	Value (v/m)	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	22	1.22	61.0	2.50	2.30	4.80	1.09
February.....	21	....	63.1	2.23	2.06	4.29	1.08
March.....	25	....	51.3	2.69	2.47	5.16	1.09
April.....	23	....	47.1	2.81	2.73	5.54	1.03
May.....	22	....	45.4	2.82	2.68	5.50	1.05
June.....	17	1.19	45.1	2.87	2.74	5.61	1.05
July.....	11	1.25	45.4	3.03	2.84	5.87	1.07
August.....	10	....	48.2	2.87	2.59	5.46	1.11
September.....	14	....	46.9	2.84	2.54	5.38	1.12
October.....	23	....	46.1	2.37	2.08	4.45	1.14
November.....	22	1.21	62.5	2.26	1.90	4.16	1.19
December.....	20	....	77.8	2.05	1.72	3.77	1.19
Totals and means..	230	1.22	53.3	2.61	2.39	5.00	1.10

15, 1941, and by Observer-in-Charge J. H. Nelson thereafter. Table II summarizes the monthly and annual values of atmospheric-electric elements.

The line-connections to the electrodes were maintained through the courtesy of the Bell Telephone Laboratories.

Cape Town and Hermanus Magnetic Observatories, South Africa. Cooperation with this Observatory of the Trigonometrical Survey of the Union of South Africa, Dr. A. Ogg, Magnetic Adviser, was continued through the loan of CIW magnetometer 17 with earth-inductor attachment. Transfer

the extension of ionospheric and auroral work there, for the period July 1, 1941 to June 30, 1942, were prepared and the required absolute equipment was standardized at Cheltenham Magnetic Observatory. At the end of the report-year, the variation and absolute observatories used during the International Polar Year of 1932-1933 had been restored to their original positions, variometer-piers cast, azimuth determined, and the installation of the insensitive magnetograph (about 25 γ /mm in all elements) almost completed. (For other details and personnel see pp. 80, 85.)

United States Antarctic Expedition's Observatory, West Base, Antarctica. The United States Antarctic Expedition, in the equipping and training of personnel for which the Department cooperated, returned to the United States in May 1941. Roy G. Fitzsimmons, physicist, has been assigned to the Department to complete reduction of the magnetic records. Arrangements have been made for assignment also of Murray A. Wiener, assistant physicist, beginning in July 1941, to compile the auroral data.

The Expedition arrived, aboard the U.S.M.S. *North Star* and U.S.S. *Bear*, at the Bay of Whales, Antarctica, January 12, 1940. For two months all available man power was required for the transportation of supplies and the erection of the base-camp—named “West Base”—5 miles from the site of the two previous Byrd expeditions at Little America and 2 miles from the edge of Ross Barrier. Its position was latitude $78^{\circ} 29' 1$ south, and longitude $163^{\circ} 51' 0$ west.

Reporting on the *magnetic program*, Fitzsimmons states that construction of the variation-observatory was begun March 18, 1940, by himself and Wiener. The work was retarded by frequent and strong blizzards. The building was placed 3 feet below the surface, the base of the magnetograph-pier first having been set an additional 4 feet down. The building (14 by 8 feet with an entrance vestibule) had an outside covering of plywood and an inner layer of canvas, providing a 4-inch dead air-space in the walls. The absolute observatory (8 by 8 feet) was erected 70 feet from the variation-observatory and both were connected with the living-quarters by a tunnel over 300 feet long, dug in May at prevailing temperature of -49° C.

The azimuth-mark was a seismograph-lamp set in the floor of the tunnel, 250 feet from the absolute observatory. Its azimuth was determined by Leonard Berlin, surveyor of the Expedition. A redetermination before departure showed the mark had changed its azimuth $10'$ in a counterclockwise direction because of the shifting of Ross Barrier.

Regular recordings with the magnetograph began April 25, 1940. The magnetograph

was of the la Cour insensitive type, loaned by the United States Coast and Geodetic Survey, and was operated on a scale-value of 29γ per mm for the horizontal (*H*) and vertical (*Z*) components and $10'$ per mm for declination (*D*). The *D*- and *H*-magnets were aligned within $30'$ of the magnetic meridian and prime vertical, respectively, and the *Z*-magnet was balanced within $30'$ of the horizontal plane. The orientation of the variometer-magnets was tested by the magnetic method. Scale-values were taken once a month by the magnetic method. Time-control marks were made by clock through the time-control switchboard located in the “Science-Building.” The clock-error was always less than 30 seconds. Magnetic records were lost on several occasions because of stopping of the recorder-clock at extremely low temperatures. It was necessary when the temperature in the variation-observatory dropped below -29° C to heat the vestibule with a kerosene lamp in order that the clock might function. The daily range in temperature in the variation-observatory was less than 1° C, except when a strong wind was blowing on the surface; the range in temperature throughout the year within the observatory was from -10° to -33° C.

Temperatures of from $+5^{\circ}$ to $+10^{\circ}$ C were maintained in the absolute observatory during observations by three circular-wick kerosene lamps. The absolute instruments—CIW magnetometer no. 8, and CIW dip-circles 241 and 242—were loaned by the Department.

Three-hour-range indices, *K*, for geomagnetic activity were transmitted weekly by radio to the United States Coast and Geodetic Survey and the Department of Terrestrial Magnetism in Washington.

Recordings with the magnetograph were discontinued January 22, 1941, at which time the observatory was dismantled and the instruments were packed for return to the United States. Preliminary values of the magnetic elements at West Base, based on weekly absolute observations, are: declination, $105^{\circ} 02'$ east; horizontal intensity, 10,005 gammas; inclination, $81^{\circ} 20'$ south.

Reporting on the *auroral program*, Wiener states that from arrival in January 1940 until well into March, continuous daylight prevented auroral observations. On March 21, 1940, however, when there were a few hours of darkness, the first auroral display was seen and recorded, although the routine program could not be started until April 1, because of demands on all hands to establish camp before the winter night. Observations were made March 21 and seven individual displays were recorded. During the remainder of March no auroras were seen.

On April 1, 1940, the sky was dark enough to allow visual observations from 07^h to 14^h GMT. The auroral program was continued until September 15, 1940, when daylight returned and Wiener took charge of the magnetic program, since Fitzsimmons was preparing for the erection of a seismic station over 100 miles from the base-camp.

Between April 1 and September 15, 1940, over 1600 individual auroral displays were observed and recorded. During this period there were 60 days on which it was possible to observe auroras, the remaining days being either overcast or in the throes of a blizzard. The method followed in making these observations was as close as practicable to that recommended by Professor Carl Störmer in *Supplements to the photographic atlas of auroral forms*, published by the International Union of Geodesy and Geophysics in 1932. The following information was recorded: station, latitude, longitude, observer, date, time (GMT), clouds, auroral form, direction, altitude, intensity, and color. In the column of remarks were recorded the movements and individual characteristics of each display.

The greater number of displays noted were of "ray-structure," appearing mostly in the forms of "isolated rays," "bundles of rays,"

and "ray-bands." The majority were of intensity 1 and 2, and white in color. There were some of intensity 3 and 4, these brighter displays being usually greenish in color and, as a rule, very active. Red and purple were also noted on occasions, and always accompanied by a very brilliant and active display.

The auroral station was on top of the Science-Building and was 5 by 5 feet, with walls rising 5 feet from the floor on all sides, thus giving a clear view of the sky in all directions from the horizon to the zenith and protection from the biting winds. In the center of the station a transit was set up, to observe the altitude and azimuth of auroras. A Contax camera, with an F 1.5 lens, was mounted on top of the transit for photographs.

Two field-trips were made to an "auroral outpost," 15 miles east of West Base, for the purpose of making parallactic photographs in conjunction with the base-camp. The first, of 7 days, began July 8, 1940, with Wiener as observer and photographer, Fitzsimmons as recorder, and Felix Ferrento (U.S.M.C.) as radio operator, the mean temperature being -54° F with a maximum low of -74° F. Dr. F. Alton Wade, senior scientist of the Expedition, took the photographs, while chief radio operator Clay Bailey looked after radio communication from the base-station. On the second trip, of 9 days, Jack Perkins was observer. These are the first observations for determinations of auroral height made in the Antarctic.

In reducing these observations, special attention will be given to the relation between auroral occurrence and magnetic disturbance. It is also hoped that some correlation can be made with the many radio observations taken during auroral displays, as well as at times when no aurora was visible.

REDUCTION OF THE "CARNEGIE" DATA

Arrangements were completed for publishing the reports on the scientific results obtained during the last cruise of the *Carnegie* in a series of volumes under the general title "Scientific Results on Cruise VII

of the *Carnegie* during 1928-1929, under Command of Captain J. P. Ault." The volumes are being published under the following classifications: physical oceanography, chemical oceanography, meteor-

ology, biology. The successive volumes under these classifications are to be numbered from I (for example, Biology—I, Biology—II, etc.; Physical Oceanography—I, Physical Oceanography—II, etc.). The reports prepared by the various authors will appear in separate volumes except in those cases where the reports are comparatively short and several may be included in one volume.

The following are now ready for publication after final editing by the Office of Publications of the Institution and by Ennis and Fleming: (a) "Biology—I: The copepods of the plankton gathered during the last cruise of the *Carnegie*," by Charles B. Wilson; (b) "Biology—II: The oceanic Tintinnina of the plankton gathered during the last cruise of the *Carnegie*," by Arthur S. Campbell.

INSTRUMENT-SHOP

The work of the Instrument-Shop totaled about 17,000 man-hours by Steiner (in charge), Lorz, Haase, Ksanda, Huff, Roes, Fogel, A. M. Schmidt, and Caherty. Major Department projects included: automatic multifrequency apparatus 3, accessories, testing, and packing of 83 cases for the College (Alaska) Observatory; construction of cyclotron parts and accessories; new high-gain amplifier and mounting for 60-inch elliptical mirror of the searchlight research; completion of automatic justifying typewriter; 90 per cent completion of primary electromagnetic standard; modification for observa-

tion in high geomagnetic latitude of magnetometer-inductor 16 for the Louise A. Boyd Arctic Expedition; instrumental repairs and adjustment of magnetometer-inductors 25 and 27; new clock-drives and cam commutators for cosmic-ray meters at Huancayo, Godhavn, Teoloyucan, and Christchurch; and numerous instrumental developments. Minor work included improvements and repairs to site, main building, cyclotron building, and searchlight buildings. R. S. Smallwood had general charge as Superintendent of Buildings, with the effective assistance of Malvin, in charge of grounds, and Quade.

MISCELLANEOUS ACTIVITIES

Members of staff took active part as delegates and officers in scientific meetings and organizations and on numerous special committees. Notes regarding lectures, addresses, and contributions to meetings and physics colloquia will be found under the section on "Publications" for each branch of work. Fleming, Forbush, Johnston, and Vestine contributed talks to the Departmental Group Conferences of the Institution, December 14, 1940, on automatic photographic recording technique, correlations of geomagnetic and cosmic-ray disturbances and possible detection of solar magnetic field from continuous cosmic-

ray data, geomagnetic effect of corpuscular and short-wave radiation, and the Earth's interior as inferred from geomagnetic variations.

Exhibits. The Department's contribution to the annual exhibition of scientific work of the Institution was limited to a private demonstration of the justifying typewriter by Root and A. M. Schmidt to the Trustees. A small exhibit of apparatus was also prepared for the meeting and symposium of the American Philosophical Society in commemoration of the life and work of Alexander Dallas Bache, at Philadelphia, February 14 and 15, 1941.

Library. The effect of the war in Europe has been manifested by the continued falling off in the number of publications received from abroad; to the diminishing production of works on geophysics in Europe, there has been added the increasing uncertainty of delivery in America. The outstanding publication dealing with terrestrial magnetism and electricity received from abroad has been the *Transactions* of the Washington Meeting of the International Association of Terrestrial Magnetism and Electricity, 1939, which was published in Great Britain. Many of the scientific journals previously received have either suspended or curtailed publication, or, in the case of the occupied countries, it has been impossible to effect their delivery to us. Despite these abnormal conditions, accessions during the report-year totaled 442, bringing the number of accessioned books and pamphlets to 26,203. As in former years, the practice was maintained of carding, classifying, and filing in the library-index all important articles of interest in current scientific journals, of which, in normal times, about 100 are regularly on file.

Librarian Harradon continued as coeditor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, dealing especially with manuscripts in foreign languages, translations, preparation of notes of interest, abstracts of publications, and quarterly lists of recent publications. He translated many memoirs of interest to staff-members. His published list of papers from the Department for 1940 indicates that the total number of publications through December 1940 was 2066. Separates of published papers were distributed regularly to interested institutions and individuals. Dove continued in charge of

the general correspondence-files and of distribution and storage of reprints.

Considerable time was spent in collecting information on the early history of geomagnetism in America, particularly in connection with the life and work of Alexander Dallas Bache, who founded the first magnetic observatory in the United States and made notable contributions to geomagnetism.

The facilities of the Library were extended to research workers from various institutions and particularly to those engaged on national-defense problems. Interlibrary loans were made with other libraries, and cordial reciprocal relations were maintained, especially with the Library of Congress.

Office administration. The usual requirements of correspondence, placing of orders, and matters concerned with accounting were greatly augmented by the many details and addition of personnel concerned with national-defense work, the construction and equipment of the Cyclotron Building, and the increased activity of the Institution's Committee on Coordination of Cosmic-Ray Investigations. The efficient office management continued in charge of administrative assistant M. B. Smith, with the assistance of Moats, Dove, Miss Gottshall, Miss Dermody, Miss Donovan, Miss Puffer, and Miss Russell.

Capello, secretary and property-clerk, had charge of shipments and inventory and prepared many manuscripts. The numerous drawings, charts, and figures for articles and lantern-slides were prepared by Hendrix, who with Ledit did the necessary photographic work. Miss Balsam kept current the files of observatory- and field-records.

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SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1940 to June 1941.* (For previous reports¹ see Year Books Nos. 32 to 39.)

Despite world conditions unpropitious for scientific investigation, the researches accomplished, in particular in the Western Hemisphere, during the year ended June 30, 1941, in the field of cosmic radiation show notable progress, improvement of technique, and discovery in an ever widening degree from both the cosmic and the geophysical viewpoints. They emphasize the value of continued support for those investigators, universities, and research organizations that have so effectively joined forces in the attack on what a decade ago seemed almost insuperable difficulties.

The number of qualified men taking co-ordinated part is surprising. The statements in the Committee's report of last year have been confirmed as regards (1) important developments in instruments and technique, (2) discovery of relations between cosmic-ray phenomena, their electrical characteristics and cosmic correlations with applications to nuclear physics, and (3) continued invaluable accumulation of cosmic-ray time-variation data in three dimensions. The researches now indicate even greater possibilities for improved knowledge of upper-air conditions and their meteorological significance. The latter development is so promising that the United States Weather Bureau is setting up four cosmic-ray stations in the United States in cooperation with Professor C.-G. Rossby at the University of Chicago.

In this inspiring exploration the Carnegie Corporation of New York and the Carnegie Institution of Washington have

taken part, on recommendation of the Committee, during the past nine years by generous grants. These have supplemented funds from many other sources, as noted in earlier reports, which have made for increased and effective coordination of effort. The following summaries and appended reports of the investigators give details of the results and progress during the year ended June 30, 1941.

Instruments. The Carnegie Institution's precision recording cosmic-ray meters were operated at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, A. K. Ludy in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, meter C-2, H. W. Wells and P. G. Ledig in charge; National Astronomical Observatory of Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquín Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory of the Danish Meteorological Institute, meter C-6, K. Thiesen and H. P. Barfod in charge.

Because of the lack of communication with Greenland, the batteries, photographic paper, and other supplies for maintaining the meter at Godhavn were forwarded from the Department of Terrestrial Magnetism through the courtesy of the United States Coast Guard and the American-Danish Greenland Commission. The De-

¹ For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.

partment of Terrestrial Magnetism has also shipped necessary batteries and other supplies to the observatories at Cheltenham, Huancayo, Teoloyucan, and Christchurch.

Comparison of meter C-3 with meter C-1 at the Cheltenham Magnetic Observatory was completed. This comprised re-determination of the constants. The temperature of meter C-3 was artificially altered over a considerable range during the comparison; the results indicated no detectable temperature-coefficient. Meter C-3 was sent in the early part of November 1940 to Dr. A. H. Compton for special investigations prior to installation at Climax, Colorado.

Some mechanical improvements in the model C cosmic-ray meters were made by S. E. Forbush and W. F. Steiner in the instrument-shop of the Department of Terrestrial Magnetism. These included more effective clock-movements for long-continued operation at observatories, and cam-controlled contacts in the camera. These improved devices and supplemental instructions for operation were supplied for several of the meters, including that at Godhavn and the one used by Dr. Hess placed on board the Grace Line S.S. *Santa Ana* for records between New York and Valparaíso.

J. W. Beagley, at Christchurch, New Zealand, continued compilation of the cosmic-ray data obtained there.

From July 1 to October 28, 1940, S. E. Forbush was on furlough from the Department of Terrestrial Magnetism for the reduction, analysis, and interpretation of the cosmic-ray data obtained at the Committee's five stations. From August 19, 1940, to October 28, 1940, Mr. Forbush devoted more than half his time to national-defense work. From October 28, 1940, he has been on leave of absence to devote full time to national defense. The Committee also lost the excellent services

of F. R. Eldridge, Jr., who took up work for national defense on September 10, 1940. Fortunately it was possible to replace Mr. Eldridge by Miss Isabelle Lange on September 19, 1940, for the reduction of cosmic-ray data.

Investigations. Professor Robert B. Brode at the University of California completed tests of his magnet for automatically recording cloud-chamber tracks in the study of cosmic rays. His experiments were slowed up because of national-defense assignment, and the services of only one assistant have been available.

Professor A. H. Compton and associates at the University of Chicago made good progress in the extensive program there. Among the studies provisionally completed and results are the following: (1) Mountain experiments with cosmic rays in latitude-effect for soft versus hard component with counter-tubes show a slightly greater effect for the soft component; (2) time-variations of changes of ionization at high altitudes show both magnetic and seasonal changes several fold greater than at sea-level; (3) the composition of cosmic rays shows (*a*) identification of abundant slow mesotrons with some occurring in pairs, through cloud-tracks in airplanes up to 9 km, (*b*) increase in relative number of showers at great depths, chiefly penetrating charged particles, through shower-experiments and cloud-tracks in mines, and (*c*) 25 per cent excess of positive mesotrons, from relative number of positive and negative mesotrons and energy-distribution at sea-level up to 10^{10} electron-volts; (4) properties of the mesotron are determined as follows: (*a*) law of abundance valid to 1500 m water, through penetration and identification of mesotrons in deep mines, (*b*) mesotron radioactive with mean life under 2.5 microseconds, results being affected by production of mesons, through disintegration of mesotrons by dissipation

in air versus graphite, and (c) Coulomb scattering plus nuclear scattering, through scattering of mesotrons in tungsten. Many of the data have been obtained with the support of the Commission on Cultural and Commercial Relations with Latin America and through cooperation with cosmic-ray investigators of Latin America in an extensive program at high altitudes on mountains, on balloon flights, at sea-level, and in deep mines carried through in Mexico, Peru, Bolivia, and Brazil.

S. E. Forbush at the Department of Terrestrial Magnetism continued his statistical analyses of hourly values of cosmic-ray ionization, bursts, and barometric pressure from Cheltenham, Christchurch, Godhavn, and Huancayo. He has established more critical tests for existence of sidereal and 27-day variations and world-wide changes.

Dr. V. F. Hess at Fordham University has obtained and evaluated cosmic-ray records on four cruises of the S.S. *Santa Ana* between New York and Valparaíso, for investigation of effects of latitude and atmospheric temperature. The automatically recording twin telescope for counting mesotrons was installed at Fordham and operated from March 23, 1941. A good (negative) correlation is found between intensity of mesotrons and mean atmospheric temperature as well as ground-temperatures. Preliminary computation of the lifetime of mesotrons indicates it to be 8×10^{-7} second—considerably shorter than ordinarily assumed.

Dr. T. H. Johnson at the Bartol Research Foundation, in further consideration of his results (see Year Book No. 39) on the slight east-west asymmetry of cosmic radiation in high latitudes, developed equations which required the assumption, to accord with observed data, that 10 to 20 per cent of total radiation consists of positives unbalanced by an equal number of

negatives. His results with the large Wilson cloud-chamber indicate a cross-section for interaction of mesotrons with strictly nuclear forces of about 3×10^{-28} cm²—a value agreeing closely with that expected from some theories of mesotrons and definitely opposed to others. The design of a high-pressure Wilson cloud-chamber was made and construction begun through a special allotment made by the Carnegie Institution of Washington in March 1941, for determining the masses of the rays involved. From coincidence-counter measurements of interaction between slow mesotrons and atomic nuclei it was concluded that nuclear-energy losses were undetectably small in comparison with those resulting from ionization.

Dr. S. A. Korff at the Bartol Research Foundation has in progress discussion of the long-period records obtained with two Millikan-Neher meters on the United States Antarctic Expedition, and is examining fluctuations for correlations with external temperature, magnetic disturbances, and upper-air meteorology. He finds that the theory of proportional counters satisfactorily explains observed data in terms of discharge mechanism. His discovery that methane is a good gas for proportional counters provides a new and simple technique for many types of ionization measurements. The radio methods of measurements by balloons were further improved and the study of the disruption of nuclei by high-energy radiation is being continued. Comparison of radioactive neutron-sources has suggested procedures for manufacturing reproducible neutron-sources.

Dr. R. A. Millikan at the California Institute of Technology, despite the diversion of many of his group to national-defense problems, reports considerable progress in the two largest undertakings: (a) building of a large cosmic-ray magnet and cloud-chamber for more accurate and more de-

pendable determination of the nature and properties of mesotrons, and (*b*) accumulation of data on origin and energy-distribution of incoming cosmic-ray particles. The difficulties of construction of the high-resolution cloud-chamber were overcome and actual photographic recording is now ready to begin. Testing in India and elsewhere of a hypothesis as to origin of cosmic rays made possible the prediction of five definite vertically incoming cosmic-ray bands and the hypothesis of four plateaus of constant incoming cosmic-ray energy. The comparison of prediction and experiment is to be further tested by new experiments in Mexico and the United States.

The Committee has maintained contacts by correspondence and personal conferences with many investigators during the year. To those named in this report and many more the Committee is indebted for constructive suggestions and counsel. Grateful acknowledgment is also made to the directors and staff-members of the organizations which continued their contributions and services to the program; these include the Danish Meteorological Institute, the National Astronomical Observatory of Mexico, the New Zealand Department of Scientific and Industrial Research, the United States Coast and Geodetic Survey, and the Carnegie Institution of Washington.

The publications listed in the accompanying reports of investigators, who have received grants through the Committee, afford ample evidence of progress and of the immense amount of productive research under way. Many fundamental conclusions appear to be on the point of attainment.

W. S. ADAMS
J. A. FLEMING, *Chairman*
F. E. WRIGHT

COSMIC-RAY MAGNET

ROBERT B. BRODE

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The study of cosmic-ray mesotrons requires a magnet that will appreciably deflect a particle with an energy of 10^{10} electron-volts. Such a magnet has been constructed with funds provided by the Carnegie Institution of Washington. Its design and dimensions were determined by a careful study of a number of $\frac{1}{8}$ scale models. In the final magnet 5300 pounds of steel were used in casting the yokes and 2700 pounds of copper wire were used in the coils. The design chosen consisted of two cast-steel yokes, with truncated-cone poles 10 inches high, 18 inches in diameter at the base, and 12 inches in diameter at the top.

A rather large coned hole through the front pole of the magnet permits direct photography of the entire chamber, 30 cm in diameter. Reluctance equivalent to an air-gap of 12 cm is introduced by this hole. The use of a mirror at 45° instead of the hollow pole would have required an air-gap of 18 cm, and it is likely that undesirable distortions in the curvatures of tracks would have been introduced by reflection from the mirror.

The coils were wound with no. 6 square double-glass-covered copper wire cemented together with an air-drying binder. The cooling of the magnet was provided by circulation of water in four layers of copper tubing in each coil. In operation with power-input of 6 kilowatts, the temperature of the pole-face and cloud-chamber actually lowers about a degree, because the tap water is about 4° C below the temperature of the room.

With a gap of 8 cm between the nearest iron parts in the magnet and with power-input of 6 kilowatts, the field in the illuminated region of the cloud-chamber is 11,000

gauss at the center, 10,200 gauss at 10 cm from the center, and 10,000 gauss at 15 cm from the center.

The magnet has been installed in a balcony on the third floor of the University of California Physics Laboratory, so that only a thin sheet of corrugated iron is above the cloud-chamber. The magnet has been supplied with a control-panel which provides the necessary cycle of operations for automatic photography of cloud-chamber tracks. In the proper sequence, initiated by a multiple-coincidence Geiger-counter circuit, the chamber expands, the magnet-current is cut off, the clearing field is reduced, illumination is initiated, the film is reset, two slow clearing expansions are given the chamber, the magnet-current is turned on, and the apparatus is reset for another picture.

The pressure of national-defense work following completion of the magnet has slowed up considerably the experiments planned, for which only one assistant is now available.

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REPORT ON COSMIC-RAY RESEARCH AT THE UNIVERSITY OF CHICAGO

A. H. COMPTON

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Studies of cosmic rays in Latin America.

A distinctive aspect of the cosmic-ray studies carried on by the University of Chicago during the year 1940-1941 was the work done in Latin America. Ever since our 1932 geographic survey of cosmic-ray intensities, we have had a special interest in the differences between the rays observed near the magnetic equator and those at

higher latitudes. During the past several years a series of problems has arisen that has demanded the study of these differences at high altitudes. It has become important also to carry on cloud-chamber and counter-tube studies at higher altitudes than are attainable on mountains in the United States. At the request and with the partial support of the Committee on Cultural and Commercial Relations with Latin America, we have accordingly organized and carried through an extensive program of high-altitude studies in Mexico, Peru, Bolivia, and Brazil.

With regard to cultural relations the study of cosmic rays offered a unique opportunity. It happens that most of the productive Latin American physicists are themselves investigators of cosmic rays, and especially those in Brazil had been urging us to come to work with them. In each country our studies thus became a cooperative enterprise. In Mexico the scientific personnel of the University and the National Astronomical Observatory, in Peru the Huancayo Magnetic Observatory (Carnegie), the Cerro de Pasco Corporation, and the University of San Marcos, and in Brazil the University of São Paulo and the Meteorological Office gave us all possible aid. As a climax there was held in August 1941, under the auspices of the Brazilian Academy of Sciences at Rio de Janeiro, a four-day conference on cosmic rays, which was widely attended by physicists and other scientific men from all parts of their country.

This program absorbed for a period of eight months the major scientific effort of the seven members of our research corps who went to Latin America. Judging by the cordial response both from the Latin Americans and from the representatives of our State Department, it would appear that its effect in developing cultural coop-

eration and unity throughout America was well worth the effort.

The main scientific objectives were likewise attained.

The data obtained have not yet been analyzed in detail. Donald Hughes and Ernest Wollan, working at an elevation of 4750 meters at the San Cristobal Mine in Peru, secured a group of striking cloud-chamber photographs showing examples of groups of mesotrons produced in the apparatus, and likewise of protons of intermediate energy. Norman Hilberry and Ann Hepburn Hilberry, working on El Misti in southern Peru, studied giant showers up to a height (5840 meters) sufficient to pass the peak of multiplication of the larger showers, thus placing on a more secure basis the cascade-interpretation of their origin. William Jesse and Paulus Pompeia, with the collaboration of Professor Wataghin, Dr. Ochialini, and others of the University of São Paulo, sent six sets of balloon-carried equipment to altitudes of over 14 miles. Of these, four were recovered and gave usable records. Dr. Joaquín Gallo, of the National Astronomical Observatory of Mexico, and Professor Alfred Baños, of the University of Mexico, aided the writer in recalibrating the model-C meter at Teoloyucan.

Cosmic rays in the high atmosphere. W. P. Jesse, Marcel Schein, and E. O. Wollan have found that mesotrons are abundant in the cosmic rays even at altitudes corresponding to pressure of 2 or 3 cm of mercury. They have shown further by absorption tests that no appreciable number of electrons of primary cosmic-ray energies hit the atmosphere from outside. Reasoning by exclusion, they conclude that *the primary cosmic-ray particles are probably protons*, which give rise directly to mesotrons as radiation when they strike the upper atmosphere. This conclusion is identical with a hypothesis advocated by W. F.

G. Swann and earlier by Ross Gunn; the supporting evidence now brought forward is, however, much more direct.

Carried by a flight of fifteen or twenty large rubber balloons was an assembly of Geiger-Müller counter-tubes, and a photographic recorder to register coincidences between various groups of counters. In one type of experiment, four or five counters were placed in line with lead between. It was found that the coincidence counting rate was almost as great for 16 cm of lead as for 4 cm of lead between the counters. Had the primary cosmic rays been electrons, most of them should have penetrated the atmosphere to the pressure of 2 or 3 cm of mercury, and have passed through the 4 cm of lead, but all should have been stopped by the 16-cm block. The fact that very few particles with these properties were detected means that the primaries are not electrons.

A second series of experiments identified the penetrating particles observed at these altitudes as secondary rays, presumably mesotrons. The number of primary particles striking the atmosphere can be calculated (as Millikan and his collaborators have done) from a knowledge of the total cosmic-ray energy reaching the Earth and the average energy of each particle. The number as thus calculated is about 12 cm^2 per minute at the latitude of Chicago, and only a few per cent of this number near the magnetic equator. Balloon experiments in Chicago, Texas, and Brazil show, however, a change with latitude of only about a factor of 2 in the penetrating rays observed at high altitudes. Near the equator their number is greatly in excess of the calculated number of primaries. The particles being studied must thus consist chiefly of secondaries produced at yet higher altitudes. Their great penetrating power identifies them as mesotrons.

Marcel Schein has been developing the

theory, suggested by Swann, that mesotrons are radiated in considerable numbers, of the order of 10, when a primary proton interacts closely with the protons in the nuclei of atmospheric atoms. The experiments of Jesse, Schein, and Wollan have given some direct support to this hypothesis, and its consequences have been shown to be in qualitative accord with our knowledge of the latitude, altitude, and directional properties of the penetrating component of the cosmic rays. It is as yet uncertain, however, whether the soft component can be wholly accounted for as resulting from the radioactive disintegration of such secondary mesotrons.

W. P. Jesse has completed his study of the time-variation of cosmic rays at the altitudes (2 to 3 cm mercury) attainable with balloons. At intervals of about a month for a period of over two years, ionization-observations have been made. As reported last year, in addition to the variations following the changes in the Earth's magnetic field, he identified a marked seasonal effect with its maximum in March. In the light of the experiments just described, which show that even at these high altitudes the observed phenomena are mostly due to mesotrons produced at yet higher altitudes, it is permissible to consider this seasonal effect as a temperature-phenomenon, just as is the seasonal effect at sea-level. A suitable method of testing this hypothesis would be to run similar experiments to determine the phase of the high-altitude seasonal effect in the Southern Hemisphere. We cannot, however, undertake such experiments at this time.

Experiments at intermediate altitudes. From our earlier work it was evident that mesotrons are being produced in increasing abundance at altitudes above 20,000 feet. Now we find that the production of mesotrons occurs in significant numbers at high mountain altitudes, and that they occur

frequently, perhaps always, in groups containing both positive and negative particles. Many protons are also observed at these altitudes. Some of them are apparently secondaries from neutrons, others may well be primary cosmic-ray particles that have penetrated the atmosphere to these depths.

These results have come chiefly from cloud-chamber experiments by Winston Bostick, Donald Hughes, and E. O. Wollan in an airplane, on mountains in Colorado and Peru, and in the laboratory. The completion of a large permanent magnet, giving 1200 oersteds at the cloud-chamber, has made possible the identification of protons and mesotrons and the distinction between positive and negative rays in these experiments.

Bruno Rossi, with the help of David Hall, has continued his study of the rate of disintegration of mesotrons. He has now succeeded in showing that *the mean lifetime of the mesotron is quantitatively proportional to its kinetic energy*, in accord with the prediction of the Lorentz transformations. This is a significant new test of Einstein's theory of relativity.

Evidence that neutrons can excite ionizing rays capable of penetrating thick blocks of lead has been found by Bruno Rossi and Victor Regener, working with counter-tubes, heavily shielded with lead, on Mount Evans. In the light of the supporting evidence of a cloud-chamber photograph taken by E. O. Wollan, it would appear that the ionizing rays thus produced may be not mesotrons but protons.

A surprisingly effective method of calculating the energy-distribution of the incoming cosmic-ray particles in the higher part of the energy-range has been introduced by Norman Hilberry. He has measured the frequency of occurrence of giant cosmic-ray showers at different elevations up to 14,000 feet, and has sought the energy-distribution of the primary particles that

will fit his data. For the higher altitudes, he finds that a law of the form

$$dN = E^{-1.7} dE$$

(dN =number of particles with energy between E and $E+dE$) not only fits his own observations, which are concerned with energies above 10^{13} electron-volts, but also agrees with the number of penetrating particles of energies above 5×10^9 electron-volts as determined by other methods. Departures at lower altitudes from the number of showers calculated from this law are interpreted, in accord with direct observation, as due to the presence of mesotrons, in addition to high-energy electrons and photons, in the giant showers.

Sea-level studies. Volney Wilson, with the effective aid of R. N. Turner of the R.M.S. *Aorangi*, completed a series of runs studying the latitude-effect between Vancouver and Sydney for the penetrating part as compared with the total cosmic rays. Two similar sets of four-fold coincidence-counters were used, one with and the other without 10 cm of lead between the counters. A preliminary analysis of the results shows a slightly greater latitude-effect for the soft part of the rays, but greater only by about the amount to be expected if the soft component at sea-level arises from the penetrating component at several hundred meters above sea-level.

The azimuthal distribution of cosmic rays at latitude 20° north has been studied in northern India by P. S. Gill. His results are roughly, but not quantitatively, in accord with the calculations of the effect of the Earth's magnetic field made by Hütner.

The scattering of mesotrons on traversing a thick block of tungsten has been found by F. L. Code to show the effects not only of electrical forces but also of forces of a nuclear type which vary more rapidly than the inverse square with the distance from the center of collision. As in the case of

alpha-ray scattering, it is such forces that give rise to large-angle scattering. More detailed examination of this extra scattering is being made by Leo Seren.

The recording of the cosmic-ray intensities with the five model-C meters at the fixed stations in New Zealand, Peru, Mexico, Maryland (United States), and Greenland has proceeded without interruption by the war. In last year's report was mentioned Niel Beardsley's analysis of the correlation between cosmic-ray intensity and the meteorological changes in the upper atmosphere. This has now assumed such meteorological interest that through the initiative and supervision of C.-G. Rossby, and with the cooperation of the United States Weather Bureau, *a chain of four stations throughout the United States is being established where cosmic-ray intensity changes will be recorded as a part of the meteorological routine.* The data will be submitted for analysis to the cosmic-ray and meteorological staff at Chicago. For this purpose Victor Regener is building a set of meters of simple design, in which counter-tubes instead of ion-chambers will be used.

Because of intense pressure of other activities, less attention has been paid this year to the analysis of the data coming in from the model-C meters. Nevertheless, Mrs. Monk has continued the analysis of the 27-day variation of cosmic rays to the stage where she can say that over a period of a year there is no noticeable change in its amplitude or its period. It is thus sharply distinguished from the sunspot-appearances, which persist for only a few revolutions of the Sun.

Subterranean studies. Volney Wilson and Donald Hughes have completed a series of cloud-chamber and counter-tube studies in a deep copper mine in the effort to identify more definitely the composition of the most penetrating cosmic rays. Both

above and below the 250-foot level it is found that the coincidences are produced by ionizing particles whose penetration through lead is sufficient to permit the assumption that they have themselves traversed the layer of earth above the instrument. There is nothing to indicate that the particles at the greater depths differ in kind from those at the lesser depths. It is found, however, that the number of secondary particles (always of a "soft" type) per hard ray increases with depth. It thus appears that when the energy of a penetrating ray approaches 10^{11} electron-volts it becomes a relatively efficient producer of high-speed electrons. This is indeed to be expected if the rays are mesotrons.

Changing conditions for cosmic-ray research. Our experimental technique in most of our studies has been improving rapidly. This is the result of contributions from many other laboratories as well as our own. Regener now builds hundreds of reliable counter-tubes for a single experiment, where recently a triple-coincidence counter could not be relied upon to operate consistently throughout an ocean voyage. Jesse sends 25-pound equipment into the Brazilian stratosphere and recovers it. Wilson cloud-chambers, most delicate of all instruments, armed with a heavy permanent magnet and automatically operated by counter-tubes, are used successfully in airplanes, on mountains, and in mines. Groetzinger, Wilson, Pompeia, Dershem, and others develop improved methods for recording or excluding various types of coincidences. Beardsley applies statistical methods heretofore unused by physicists. Such advances in technique are of value also in other fields of investigation.

We are most fortunate in the cordial cooperation we are receiving from other investigators. Mention is made above of some of the help received from colleagues and organizations in Latin America. An-

other striking example is the high-altitude research laboratory on Mount Evans, under the supervision of Professor J. C. Stearns of the University of Denver, and supported largely by the University of Denver, the Massachusetts Institute of Technology, the University of Chicago, and Cornell University. This is the result of work started by Stearns and ourselves in 1931, which has now grown until this past summer no less than eight cosmic-ray expeditions from five different laboratories have used its facilities.

Cosmic-ray studies have aided in promoting international scientific collaboration between the countries in the Western Hemisphere, and in training a group of able men in methods of attacking new and difficult physical problems. We see, however, no direct value of cosmic rays to the national defense. It is thus in accord with the needs of the times that the chief curb now placed on these studies is that caused by the need for all qualified investigators to work on national-defense tasks. Emphasis in our laboratory is thus necessarily turning away from cosmic-ray research, in spite of our confidence in its high value to the advancement of science. There remains, nevertheless, a substantial nucleus of able physicists ineligible for direct defense activities who can maintain active work on cosmic rays.

Personnel. The following research associates, instructors, and research fellows of the University of Chicago have given most of their time to this work: W. P. Jesse, Marcel Schein, E. O. Wollan, V. C. Wilson (left May 1941 for national defense), Donald J. Hughes (absent three months on national defense), Bruno Rossi (until October 1940), Ardis T. Monk, Elmer Dershem, N. F. Beardsley, P. S. Gill (until April 1941), and Victor Regener. As guests of the laboratory, Gerhart Groetzinger (until 1941), Paulus Pompeia, and Ann Hepburn Hilberry have made valuable cosmic-

ray studies. As graduate students the work of Norman Hilberry and Winston Bostick has been outstanding.

Especial thanks are due to the Works Progress Administration (project no. 665-54-3-388) for valuable help in preparing for our various experiments, to the Cerro de Pasco Corporation for housing our expedition in central Peru, to Dr. Julio Avendaño for his help with our Peruvian expeditions, to R. N. Turner for his continued care of our equipment on the R.M.S. *Aorangi*, to the University of São Paulo, the Brazilian Academy of Sciences, and the Brazilian Government for their hospitality and cooperation, and to the entire staff and collaborators of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, who have continued to collect and analyze the records of cosmic-ray intensity in spite of pressure of other duties.

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STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS

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Reduction of data. Scalings and tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure were continued for the records obtained at Cheltenham, Godhavn, and Huancayo. Reduction of daily mean values of ionization to constant barometric pressure were also continued for Cheltenham, Christchurch, Godhavn, and Huancayo.

Reductions to constant barometric pressure of the bihourly mean values of ionization for each day were completed through July 1940 for Cheltenham, and for periods totaling three and one-half years for Huancayo. These data provide a much better sample than has previously been available for adequate statistical analyses of the solar diurnal variation and its variability and

cause. They provide also a better basis for more critical tests regarding the existence of sidereal variation and of the persistent 27-day variation, as well as for continued studies of world-wide changes.

Intercomparison of cosmic-ray meters. The intercomparison of cosmic-ray meter C-3 with meter C-1 at Cheltenham, which was mentioned in last year's report, was continued to October 25, 1940. These data indicated a systematic change, apparently exponential with time, in the differences between daily means from the two instruments. Whether this may be ascribed to radioactive contamination is not certain, but it emphasizes the necessity of thorough comparisons, over considerable periods, of cosmic-ray meters to be used for determining slow changes in cosmic-ray intensity with time. Meter C-1 had previously been shown to be free of any temperature-coefficient, and the comparison between data from it and from meter C-3, when the latter was subjected to controlled temperature-changes, showed that meter C-3 also was not affected measurably by temperature. In the first part of November 1940, meter C-3 was sent to Dr. Compton for investigations on burst-rates.

Torily. The latitude-effect has been plotted from our results on trips 4 and 5. Correlations will be computed as soon as we have the results of one more trip available. Professor Compton is pleased with the results and suggests that our final publication should include at least one complete year's records (February 1941 to February 1942). He also lent the writer a standard condenser for the absolute calibrations which were made between June 23 and 27, 1941, when the ship was in port in New York.

Twin telescope for mesotron-counting set up at Fordham. This apparatus, completed at the Bartol Research Foundation December 1940, under the supervision of Professor Swann, was set up in January 1941 at Fordham (basement of Physics Laboratory). F. Benedetto then built an automatic device for taking bihourly photographs of the recorder-dials of the two telescopes, which are set up in such a way that every ray which passes through one set of triple coincidence-counters (telescope 1) is bound also to pass through the three trays of counters in the second set. A new type of recorder, developed by Professor Swann, is used giving the bihourly readings on both dials.

Automatic recordings were begun March 23, 1941, and the results were computed together with the radiosonde teletype records of atmospheric temperatures at 0-, 3-, 6-, and 12-km altitudes. In the graphs is also given the mean temperature of the atmosphere from 0- to 16-km altitude, as obtained from a graphical integration of the curves of temperature versus altitude, taken from the flights at Lakehurst. The temperatures are plotted upside down (as usual) in order to facilitate the comparison of the trend of the curves by eye.

A good (negative) correlation is found between the mesotron-intensity and the mean temperatures as well as the ground-

REPORT ON COSMIC-RAY WORK

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Cosmic-ray registrations aboard the "Santa Ana." Complete records have been obtained on trips 4, 5, 6, and 7 (trip 8 is in progress now [July 1941]) and have been evaluated and used for computation of the latitude-effect and the atmospheric temperature-effect. Trips 1 and 2 gave only a limited number of usable results, and trip 3 none at all, on account of defects in the old panels of the meter. Father Berry replaced the panels a few months ago and now the apparatus works very satisfac-

temperatures. Compton, Beardsley, and others agree with the writer that the parallelism is almost as good for the ground-temperature as it is for the mean temperature between 0 and 16 km.

From a scatter-diagram for a preliminary evaluation of the temperature-coefficient of the cosmic-ray-mesotron component, although the number of observations is not yet sufficient to allow a reliable computation by the correlation-method, we can safely say that the coefficient is about -0.7 per cent per degree centigrade when the mean atmospheric temperature (0-16 km) is used. If we use ground-temperatures only, the coefficient turns out to be -0.48 per cent per degree. Both values are much higher than the ones derived from the measurements by the ionization-method (-0.1 to -0.2 per cent). This is quite a surprise, and we must conclude that, on the basis of Blackett's theory of the temperature-effect on cosmic-ray intensities, it can be explained only by assuming that the mesotrons reaching our apparatus (after penetrating through four ceilings and floors and through 22 cm of lead) must have a considerably shorter lifetime than is ordinarily assumed. We compute a lifetime of 8×10^{-7} sec (instead of 2×10^{-6} sec). Our results roused much interest in Chicago, and they support conclusions derived from high-altitude flights by Schein, Jesse, and Wollan.

Benedetto and the writer will continue this interesting piece of work, and we hope to send a preliminary paper to the *Physical Review* within the next weeks. For the final publication we shall collect at least one year's data, in order to have all seasonal effects and to get a good picture of other time-variations as well.

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STUDIES OF COSMIC RAYS

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Studies made during the year ending June 30, 1941, under grants from the Carnegie Institution of Washington have been directed to the problems of (a) the composition of the cosmic radiation in the atmosphere, (b) the production and absorption of the mesotrons which constitute the hard component of the cosmic radiation, and (c) the interaction of mesotrons with atomic nuclei. The following investigations have been made.

Analysis of the east-west asymmetry of the cosmic radiation in high latitudes. Experiments (see report for 1939-1940, Year Book No. 39) have shown that, even in high latitudes where field-sensitive primary rays fail to reach sea-level, there is a slight east-west asymmetry of the order of 1 or 2 per cent. As an explanation of this experimental effect, theoretical analysis was made of the deflection of high-energy primary cosmic rays by the Earth's magnetic field after the rays have been slowed down by atmospheric absorption. Equations were developed describing the orbits of such particles, and on the basis of those equations the asymmetry to be expected from the known energy-distribution was calculated as a function of the hypothetical excess of positive rays over negative. The calculated asymmetry agreed with the observed values if it was assumed that 10 or 20 per cent of the total radiation consists of positives unbalanced by an equal number of negatives. This assumption was in close agreement with the experimental measurements of

the positive excess made by Dr. D. J. Hughes. The theory thus provides an interesting interpretation of a small but puzzling effect and suggests an alternative method to that of the magnetic cloud-chamber for analyzing cosmic rays in the atmosphere.

Studies with a large Wilson cloud-chamber. The cloud-chamber described in the previous report (Year Book No. 39, p. 126) has been fitted with magnetic coils capable of producing a uniform field of 1500 oersteds, and approximately 50,000 stereoscopic photographs have been obtained. Three lead plates placed horizontally across the chamber have been used to scatter and to stop cosmic rays, and the analysis of these effects has thrown important light on the interaction of mesotrons with atomic nuclei. R. P. Shutt has undertaken an analysis of the distribution of scattering angles in lead plates of the two thicknesses used in these experiments, and he has devised a simple criterion for determining which parts of the observed scatterings are caused, respectively, by (a) the forces arising from the interaction between the charges on the atomic nuclei and those on the mesotrons, and (b) the strictly nuclear forces, nonelectric in character. On the basis of this analysis our experiments indicate a cross-section for the interaction of the mesotrons with the strictly nuclear forces of approximately $3 \times 10^{-28} \text{ cm}^2$. This value is in close agreement with that to be expected from some of the theories of mesotrons, and it is definitely opposed to others.

The principal part of the scattering observed arises from electric forces between the charges. These scatterings are generally multiple and result in a well defined pattern. From the observed pattern it is possible to use the theory to determine the distribution of the particles involved with respect to their energies. This method of

determining the energy-distribution is fully as precise as that depending on magnetic analysis, and has certain definite advantages. Further study of the energy-distribution based on the very large number of photographs now available should result in a much more precise determination of the energy-distribution of mesotrons at sea-level than anything now available, and will supply useful data for further studies of the production and disintegration of mesotrons in the atmosphere.

A special coincidence-counter arrangement has been used for distinguishing simultaneous mesotrons such as might exist if mesotrons are being produced in a lead block above the chamber or in the lead plates inside the chamber, but in none of the 50,000 photographs obtained has any evidence been found to indicate production of mesotrons in pairs or higher multiples.

New statistics on the rate of the stopping of mesotrons in lead plates have been obtained. The number of stoppages observed is in good agreement with the assumption that the principal mechanism involved is the loss of energy by ionization.

Design and construction of the high-pressure cloud-chamber. With funds made available on March 18, 1941, construction has proceeded on a new type of high-pressure Wilson cloud-chamber. The cloud-chamber itself is constructed of thin glass parts, but the high internal gas pressure, amounting to two or three hundred atmospheres, is supported by an equal external hydrostatic pressure in a bath of oil contained in a heavy steel cylinder. The model under construction has a cloud-chamber 12 inches in diameter and 3 inches deep, contained in a steel cylinder 24 inches in inside diameter and with a wall thickness of 4 inches. At the time of writing the cylinder has been practically finished by the Baldwin-Southwark Division

of the Baldwin Locomotive Works, and other parts have been nearly completed in our own shop. Our design also incorporates internally placed magnetic coils capable of producing 10,000 oersteds in the chamber.

In the chamber we shall have a gaseous stopping-power equivalent to approximately 1 cm of lead, and we should obtain frequent photographs of mesotrons being stopped in the gas. We also expect to find many examples of high-energy electrons ejected from the atoms of the gas by knock-on processes. From studies of such photographs we shall be able to determine the masses of the rays involved.

Coincidence-counter recording of cosmic-ray protons. A vigorous effort has been made to construct an instrument which will measure cosmic-ray protons and distinguish them from mesotrons or electrons. It was hoped that this instrument could be sent aloft in balloons or carried in airplanes flying in the stratosphere. The principle of its operation is based on the fact that slow protons showing an appreciably increased ionization, so that they would operate a proportional counter, should still have enough energy to penetrate a considerable thickness of the material. The first results with an instrument of this type were quite encouraging, but more recently it has appeared more difficult to make the instrument selective and still encompass a large enough range of proton-energies to give an appreciable intensity, even in the stratosphere. We have, therefore, temporarily postponed these experiments and are devoting full time to the high-pressure cloud-chamber.

Coincidence-counter measurements of the interaction between slow mesotrons and atomic nuclei. By means of an anti-coincidence technique, the numbers of mesotrons stopped in given thicknesses of light and heavy substances have been measured.

If nuclear interaction is an important absorptive process, light and heavy nuclei might be expected to react differently, and the equivalent thicknesses for equal stoppages by the two substances should be different from the thicknesses calculated on the assumption that ionization is the only absorptive process. A series of experiments has shown that the thickness of lead which stops the same number of mesotrons as 28.5 grams per cm^2 of carbon is equal to 24 grams per cm^2 , and this is very nearly the value to be expected from the ionization theory. We concluded that nuclear energy losses were undetectably small in comparison with those resulting from ionization.

Personnel. On October 1, 1940, Dr. J. Griffiths Barry left our organization to become instructor in electrical engineering at Princeton. Up to the time of his departure he was devoting full time to the cosmic-ray program. M. A. Pomerantz was devoting full time up to December 1, 1940. R. P. Shutt has been devoting full time to these studies throughout the period of this report, and Dr. Sergio de Benedetti has been devoting full time since December 1, 1940. During the interval from January 1 to June 1, 1941, we have had the assistance of Martin H. Hornstine.

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COSMIC-RAY INVESTIGATIONS

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The cosmic-ray investigations carried out during June 30, 1940, to July 1, 1941, with the aid of funds made available through the Carnegie Institution of Washington, are set forth below.

Cooperation with United States Antarctic Service. During this report-year, two of the Millikan-Neher type precision cosmic-ray meters were operated in Antarctica. The long-period records have been returned to the United States, developed, and measured. Work is now in progress on the discussion of these observations. The fluctuations observed are being examined and the correlations with external temperature, magnetic disturbances, and upper-air meteorology are being studied.

In addition to the long-term observations, one of the meters was flown to altitudes up to 22,000 feet over Little America, in order that the cosmic-ray intensity at high elevations might be compared with that in northern latitudes; the meter was also operated on board the ship returning from Antarctica. The latter record has provided additional data on pressure- and temperature-coefficients. Neutrons were measured at sea-level as a function of latitude. No effect as large as 10 per cent was observed, a result which confirmed our ex-

pectations. Present theories, however, predict a large latitude-effect at high elevations. The complete report will be prepared during the winter of 1941-1942.

Studies of proportional counters. In collaboration with Dr. M. E. Rose, a theory of proportional-counter action was developed. The theory was based on the development of the Townsend avalanche mechanism, and assumes that in certain gases and in subthreshold operation of the counters, photons play an unimportant role. It also assumes that the fluctuations in the amount of ionization formed may be neglected. Experiments were performed to test the theory, and it was found that the assumptions were valid, and that the theory correctly predicted pulse-size as a function of gas-type, gas-mixtures, gas-pressure, and geometrical size and shapes of counters. Such gases as methane, boron-trifluoride, and mixtures of argon with organic vapors were found to give good proportional-counting characteristics. In other gases, such as pure argon and hydrogen, photons were found to play an important role in the discharge, and these gases were not found suitable for proportional counters. Thus the theory satisfactorily explained counter behavior in this region, and enables us to understand what had hitherto been "observed facts" in terms of a discharge mechanism. The discovery that methane is a good gas for proportional counters provides a new, simple, and inexpensive technique for many types of ionization-measurement.

Radio-balloon measurements. The technique of automatically transmitting cosmic-ray intensities from balloons has been further developed, and a series of flights was made in which the discharges of proportional counters were transmitted from the upper atmosphere. These counters were, on different occasions, of various sizes and filled with various gases, in order to permit a separation of the several quantities mea-

sured by each. The analysis showed that slow protons as well as neutrons were present in the radiation at high elevations, and suggested that these protons were produced in processes the same as or similar to those in which the neutrons are probably produced, namely, the disintegration of nuclei by the photons in the radiation. These protons are to be distinguished from possible primary particles, and are too numerous to be primary particles which have been slowed down. The study of the disruption of nuclei by high-energy radiation is being continued.

Comparison of radioactive neutron-sources. The work started in cooperation with M. D. Whitaker, E. J. Murphy, W. C. Bright, and E. T. Clarke, on the comparison of various types of radioactive neutron-sources, has been completed. It was found that (*a*) the size and shape of the source and (*b*) the amount of beryllium used were relatively unimportant to the neutron-producing efficiency. On the other hand, the fullness of the container, the degree of the mixing of the radium or radon with the beryllium, the purity of the beryllium, and the grain-size of the beryllium were all found to be very important. Radon-sources were found, in the best cases, to be more efficient than radium-beryllium sources, owing principally to the better mixing usually achieved, but radon-sources were also found to vary widely in efficiency, so that the conventional procedure of using the gamma-ray intensity as a measure of the neutron-intensity may lead to errors as large as a factor of 2. Procedures for manufacturing reproducible sources were suggested.

Personnel. It is a pleasure to acknowledge the cooperation of many persons. In particular, Dana K. Bailey has done excellent work in connection with the Antarctic studies, both in obtaining and in reducing data. E. K. Smith has assisted in the mea-

suring of the records. E. T. Clarke has assisted with the balloon-flights and with parts of the Antarctic program. Helpful discussions have been had with H. A. Bethe and many others.

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STUDIES OF COSMIC RAYS

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During the year from July 1, 1940, to June 30, 1941, the group of cosmic-ray workers at the California Institute of Technology has had its energies largely diverted to the problems of national defense.

In spite of this diversion, however, it is able to report considerable progress in its two largest undertakings: (a) the building of a large cosmic-ray magnet and cloud-chamber for the more accurate and more dependable determination of the nature and properties of mesotrons, and (b) the accumulation of evidence as to the origin and energy-distribution of the incoming cosmic-ray particles.

Anderson and Neddermeyer's high-resolution cloud-chamber. The problems (1) of building a circular cloud-chamber 60 cm in diameter, (2) of producing an 8000-gauss field uniform throughout such an area, (3) of producing in so large a chamber sufficiently uniform expansions to avoid such track-distortion as generally places the limit on the accuracy of energy-measurements in cloud-chambers, and (4) of getting enough light at the correct instant to obtain tracks which are sharp throughout their full 60 cm of length—all these demands put together present well-nigh insuperable difficulties and require endless labor.

These difficulties, however, have been

successively overcome this year by Carl D. Anderson, assisted by Leon Katz (Neddermeyer is on defense work in Washington), and at the time of this writing the actual photographic work is ready to begin.

Millikan, Neher, and Pickering's testing in India and elsewhere of a hypothesis as to the origin of cosmic rays. The hypothesis subjected to test by Millikan, Neher, and Pickering's technique of cosmic-ray flights to close to the top of the atmosphere, made in India early in 1940 and in the United States in the summer and fall of 1941, makes possible the prediction of five definite vertically incoming cosmic-ray bands. As the observer moves north from the magnetic equator, each of these five bands should begin to reach the Earth at a particular latitude and continue reaching it at all more northerly latitudes. Between each latitude of first entrance of a band of particular energy and the latitude of first entrance of the band of next lower energy there should be found a plateau of constant vertically incoming cosmic-ray energy. Four such plateaus should be experimentally observable.

The hypothesis rendering possible these predictions rests on five major discoveries made by the workers in the Norman Bridge Laboratory of Physics at the California Institute of Technology at Pasadena. These are: (1) the discovery that more than 60 per cent of all incoming cosmic-ray energy is of the nature of incoming charged-particle bullets (either electronic or protonic), each of energy between 2 billion electron-volts and 15 billion electron-volts; (2) Neddermeyer and Anderson's discovery of the production by nuclear impacts within the atmosphere of mesotrons which serve as the chief carriers of the cosmic-ray energy down to the lower levels of the atmosphere; (3) Bowen's remarkable discovery that atoms, when out in interstellar space, are able to undergo

atomic transformations forbidden to them within the stars; (4) Bowen and Wise's discovery that in ring-nebulæ, trillions of miles away from the exciting star, and therefore presumably reflecting conditions in interstellar space, there are five atoms, namely, helium, carbon, nitrogen, oxygen, and silicon, each of which is more than ten times more abundant than any other atom save hydrogen (which must be excluded from measurable cosmic-ray effects because of the smallness of its rest-mass energy); and (5) Lauritsen and Fowler's discovery in the Kellogg Radiation Laboratory that a part at least of the rest-mass energy of an atom has the power, under suitable conditions, of transforming itself directly into the creation of a positive-negative charged-particle pair.

The hypothesis proposed in view of these five discoveries is that, whereas the evolution of energy by the stars is maintained, as Bethe has recently shown, by the *partial* transformation within the stars of the rest-mass energy of hydrogen into radiant energy through the building of helium, carbon, and other atoms out of hydrogen, and the release through this process of the so-called "packing-fraction" energy, the energy of cosmic rays on the other hand is maintained by the occasional *complete* transformation in interstellar space of the rest-mass energy of the atoms of helium, carbon, nitrogen, oxygen, and silicon (and even heavier aggregates) into cosmic rays, each such event presumably creating either an electron-pair or a proton-pair (these two events are indistinguishable by our geographic experiments), though an occasional photon-pair, or neutron-pair, need not necessarily be excluded.

The foregoing hypothesis requires that the cosmic rays of measurable energy reveal a spectral distribution of five distinct, definitely measurable bands, as follows: (1) a band of rays each having an energy

of 1.9 billion electron-volts, produced by the annihilation or complete transformation, in interstellar space, of the rest-mass energy of the helium atom; (2) a carbon-atom-annihilation band of energy 5.6 billion electron-volts; (3) a nitrogen-atom band of energy 6.6 billion electron-volts; (4) an oxygen-atom band of energy 7.5 billion electron-volts; and (5) a silicon-atom band of energy 13.2 billion electron-volts.

The hypothesis requires further that there should be in India, for vertically incoming rays, between the magnetic equator and magnetic latitude about 20° north, a plateau of cosmic-ray intensity unchanging with latitude; it requires another such plateau between the latitudes of entrance of the bands due to the silicon and oxygen atoms; it requires a third such plateau between the great band produced by the annihilation of the carbon, nitrogen, and oxygen atoms, and that due to the annihilation of helium; and finally it requires a fourth such plateau north of Bismarck, North Dakota, where, as the observer goes northward, the helium band should first be able to get vertically through the blocking effect of the Earth's magnetic field and should then be able to enter the Earth in full strength at all more northerly latitudes.

The experimental evidence that has been so far obtained in India and elsewhere for the existence of these five bands and four plateaus may be thus summarized. The India evidence seems to be good for the existence of the plateau of constant cosmic-ray intensity from the equator up to Agra (17° north) and for the appearance just north of Agra of a band that can be identified with that due to silicon. There is some evidence for the existence of the flat plateau just north of the latitude of first entrance of the hypothetical silicon band. There is unambiguous evidence for the entrance at about the computed latitude of

a very strong band at between 5.5 and 7.5 billion electron-volts, and this we tentatively identify with the joint carbon, nitrogen, oxygen bands, which, however, we have not yet been able to resolve. There is a little evidence for the existence of a plateau of constant cosmic-ray intensity between the latitudes at which the carbon and the helium bands should appear, and there is fair evidence, too, for the existence of a flat plateau north of the latitude of entrance of the hypothetical helium band, the real existence of which may be stated to have been rendered probable. Not only are all the predicted latitudes in reasonable agreement with the observations, but also the observed intensities are of the right order of magnitude.

Further experiments are being made to see whether better-designed apparatus will render the nature of the evidence better or worse for the hypothesis, and new experiments in Mexico and the United States are planned for the coming months.

This comparison of prediction and experiment has been made possible largely through the generous support of the investigation by the Carnegie Institution of Washington. The success of the work in India was made possible by the extraordinarily generous and complete cooperation of the British Indian Meteorological Service.

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MOTION OF COSMIC-RAY PARTICLES IN THE GEOMAGNETIC FIELD

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Our research activity on cosmic rays and related questions for the period from July 1, 1940 to June 30, 1941 has been at a virtual standstill, mainly because the completion of the new differential analyzer has been unavoidably delayed. Every indication at the present time points to an early completion of the differential analyzer. Within the limitations imposed by the present emergency, it is expected to have the program under way by September 1941.

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CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, California. *Cooperative researches at the Seismological Laboratory.* (For previous reports see Year Books Nos. 37 to 39.)

Investigations under way at the Seismological Laboratory at Pasadena relate not merely to the nature, distribution, and mechanism of California earthquakes, or of world earthquakes for that matter, but also to the broader questions of the structure of the earth's crust, the nature of the continents and ocean basins as units in earth structure, and the nature and constitution of the deeper shells and core of the earth. Existing instruments and installations have been maintained, but no designing of new instruments has been undertaken during the year, owing to the occupation of Dr. Benioff, the mechanical staff, and the shop facilities with defense work. The progress in research on certain of these seismic and earth-structure problems may be briefly reviewed.

The mechanism of earthquake causation.

Though it is certain that most earthquakes originate during the slipping along faults, several questions as to the mechanism remain unanswered. One is whether the forces causing the slipping are local and relate only to the fault and adjacent parts of the crust, or whether they are applied regionally and affect enormously larger areas including scores of faults. Analyses of hundreds of southern California earthquakes, originating on many different faults, seem to indicate that the forces causing the shocks are in every case applied in approximately the same direction. Gutenberg finds that, if all the faults are assumed for convenience to trend north and south, the initial impulse at seismographic stations located in the northwest and southeast quadrants is invariably compressional, and in the northeast and southwest quadrants it is rarefactional. The inference is that the whole of southern California is

under strain, and that the force is applied in such a way as to produce shear, with the west side tending to move northward with reference to the eastern part of the affected area. This inference agrees with a conclusion also reached by Buwalda from study of the surface features of numerous active faults in California, in which it was found that in each case the west side of the fault has been moving northward. The forces can of course be applied to the eastern and western margins of the sheared area, or, as seems more probable, they can be applied through underflow, the subcrust moving slowly and dragging the crust with it. This is obviously a very important and fundamental problem in earth tectonics. Other seismic areas for which adequate records are available should be investigated in the same manner.

Continental structure. Seismology has added enormously to our knowledge regarding the nature and origin of the continents and ocean basins. Two researches prosecuted in the Seismological Laboratory during the past year or two have thrown much light on this problem. Gutenberg and Richter have reinvestigated the distribution of earthquakes over the surface of the earth, correcting earlier location data where necessary. Though slight shocks apparently occur everywhere, the stronger and more important earthquakes practically all originate in certain zones, of which the circum-Pacific and the Mediterranean-Himalayan are the two most important. The blocks between the active areas are relatively inactive, especially the shield areas of old crystalline rocks which form the cores of most of the continents. These inactive areas have, however, experienced strong mountain-making in past geological

periods, as is indicated clearly by their structure. The inference is that, however the forces may be applied, failure of the crust, in the form of the crumpling which causes earthquakes, is at present limited to certain zones.

The investigation of the distribution of shallow, moderately deep, and deep focus earthquakes by Gutenberg and Richter around the Pacific basin has indicated that the deeper the shock, the farther inland in general lies its focus or origin. This seems to indicate that shearing forces are being applied, causing earthquakes along the border of the Pacific basin and presumably resulting from differential movement of the continental masses on the two sides of the Pacific basin with reference to that basin. Other studies made here previously had shown that no granitic continental layer exists beneath the Pacific, its floor being made of the heavier basaltic material which underlies the granitic layer constituting the continents. The importance of these studies for an understanding of the continents is clear, but they need to be extended.

Mountain structures. In a detailed study of the internal structure of the continents it is found that earthquake waves do not travel with the same velocity in different directions, along and across the structural grain of the region, or through mountain ranges. At Pasadena, waves arriving from the south and traversing the Los Angeles basin, which is filled to a depth of 8 or 9 miles with sediments, are weak, and from Victorville in the Mohave Desert they arrive too early. The exact cause of these differences deserves further investigation, for a full understanding of it would doubtless aid in gaining a comprehension of structures in the crust not readily discernible at the surface.

Some clues have been secured recently to a solution of the problem whether mountain ranges have roots, that is, whether they

extend as structures deep down into the crust as well as project above its surface. The initial wave of earthquakes originating on one side of the Sierra Nevada arrives at seismographic stations on the opposite side after an interval considerably longer than the calculated time. The sedimentary strata folded in making the original Sierras have been almost entirely eroded off the range, and in any case the velocity of earthquake waves through them, since they are now crystalline, is probably not less than through the granite which now forms the bulk of the mountain mass. The best inference seems to be that the granite, which has a lower velocity than the underlying basalt, extends deeper down into the crust beneath the range than it does in the surrounding country, and delays the arrival of the initial waves. Because of the bearing which this inference has on the nature and origin of mountains in general, this subject should be investigated further.

California earthquakes. The careful analysis, mainly by Richter and Rogers, of the numerous small and occasional larger shocks being recorded by the excellent equipment operating at the Pasadena Laboratory and the seven outlying stations in southern California is continuing, and a large amount of valuable data is accumulating for the solution not merely of southern California seismic problems, but also of general and theoretical earthquake questions. Of local interest are of course such matters as the relative activity of different faults in the community, the probable accelerations to be expected in future shocks —these figures forming a basis for computations by engineers and architects in designing earthquake-resistant buildings—and the earthquake risk in the territory. General or fundamental questions gradually receiving answers from the accumulating data are such as these: How deep are the faults which originate the shocks? And

hence how thick is the crust which is being sheared? The stronger earthquakes originate on the faults, but slight shocks seem to occur at all points between the active faults, in the great earth blocks miles wide and tens of miles long; what does this mean as to the nature of the crustal failure which is occurring? Epidemics of earthquakes occur for a period of months or a few years in a certain area, then cease, and the scene of activity shifts; what does this mean as to the nature of the forces causing the deformation? How are the forces applied, whether on the east and west sides of the strip in California experiencing horizontal-slip faulting, or by underdrag from slow movement of the subcrust? Can place and time patterns of light shocks be used for forecasting destructive shocks? Do all the data from the records accord with the elastic rebound theory of earthquake causation? What is the time distribution of the energy radiated in given strong earthquakes? Does the energy radiated bear some close correspondence to the magnitude of slip on the fault causing the shock? Answers to these and to many other questions will be needed before earthquake phenomena will be understood very fully.

Routine activities. Dr. Gutenberg is now revising the standard travel-time data for southern California. The new stations at Palomar, Fresno (University of California group), and Lake Mead, and the improvement at Tucson, permit the determination of epicenters and structures with greater accuracy than ever before, so that it is now possible to investigate local differences within the region. Further improvement is to be expected with the projected installation of Benioff instruments at the Lake Mead stations, and with the completion and installation of the four semipermanent stations for our local program, now postponed on account of defense work. Even for epicenters previously considered well

located, it appears that the effect of local differences may change the location by several kilometers. This general improvement makes it more desirable than ever to have the recording and cataloguing of local earthquakes continue unimpaired over a long series of years.

For use in revising epicenters and travel times, Dr. Richter has set up tabulations simplifying the calculation of short distances from epicenter to station; differences in latitude and longitude are converted into kilometers of the meridian and the mean parallel, and combined as sides of a right triangle. These results are used in a simplified application of the Geiger method for determining epicenter and origin time with given velocities modified for use with a computing machine. A solution with velocity as an additional unknown has been set up and carried out with little additional labor.

The time difference between arrival of P from distant shocks at Tucson and at Pasadena shows great regularity for shocks in any given region; a chart has been constructed from these observed time differences, which facilitates approximate locations.

The magnitude scale (introduced by Dr. Richter) is being applied regularly to large distant shocks. The first great earthquake (magnitude approaching 8) since 1939 occurred on June 26, 1941, in the region of the Andaman Islands. The Pasadena magnitude scale is now being used by workers in India and New Zealand. In the latter country the results are directly comparable with those in southern California, and show a very satisfactory degree of agreement.

The pattern of minor shocks in southern California shows no significant change subsequent to the large Imperial Valley shock of May 1940. Observations over a long period of years are clearly necessary

to establish results of this kind, as well as to provide enough well observed large shocks for detailed investigation.

During the year July 1, 1940 to June 30, 1941, five potentially damaging shocks (magnitude 4.5) occurred in southern California. On June 30, 1941, a shock of magnitude 6 took place in the Santa Barbara Channel 10 miles southeast of Santa Barbara. Effects were investigated in the field by Dr. Buwalda and Dr. Richter. Intensity VII, Mercalli scale (damage to weak structures), was found at Santa Barbara and Carpinteria. The shock was felt as far away as San Bernardino. Aftershocks were numerous.

On January 29, 1941, a shock of magnitude 4 occasioned some alarm in and near Pasadena. The instrumental epicenter is within the city limits of Whittier. This result is very accurate, and is of much geologic and economic interest, since it adds another to the short list of shocks probably associated with the Norwalk fault, which is shown to be a source of serious danger to at least the eastern part of the Los Angeles metropolitan district.

Several important shocks occurred in northern California. The two largest (magnitude 6) were on February 9 and May 13, off the coast of Humboldt County.

Three Benioff microbarographs were set up during the winter in a triangle with sides of about 100 meters. The records show that pressure waves arrive from southwesterly or westerly directions with largest amplitudes when a low-pressure area is at sea off southern California.

During the year the following papers were presented: At the meetings of the Geological and Seismological Societies of America at Stanford University in April: J. P. Buwalda and C. F. Richter, "Imperial Valley earthquake of May 18, 1940"; B. Gutenberg, "Mechanism of faulting in southern California indicated by seismograms"; C. F. Richter, "Earthquake near Whittier, California, January 29, 1941." At the meeting of the American Geophysical Union at Washington in April: B. Gutenberg and H. Benioff, "Pressure-waves in the atmosphere near Pasadena"; B. Gutenberg, "Tectonic processes now in action." At the meeting of the American Association for the Advancement of Science, Pacific Division, at Pasadena in June: B. Gutenberg and C. F. Richter, "Earthquakes and submarine topography"; B. Gutenberg, "Eustatic changes."

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UNIVERSITY OF PITTSBURGH, Pittsburgh, Pennsylvania. *Studies of high-precision calorimetry in dilute solutions*

These studies were carried on in cooperation with the Geophysical Laboratory of the Carnegie Institution of Washington.

Dr. William E. Wallace began his fel-

lowship work on September 15, 1940. By the end of March he had completed a study of the heats of dilution of aqueous cadmium chloride, bromide, and iodide

solutions at 15° and 25° C. The results of this investigation were presented by Wallace and A. L. Robinson at the St. Louis meeting of the American Chemical Society, to the symposium on "Thermodynamics of Electrolytic Dissociation" of the Section of Inorganic and Physical Chemistry. The papers presented at this symposium are probably to be published in the December 1941 issue of *Chemical Reviews*.

Dr. Wallace is at present measuring the heats of dilution of CaSO_4 and the heats

of solution of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ in NaCl solutions of various concentrations. It is likely that this work will be completed by the end of July or earlier. It is then proposed to measure the heats of dilution of electrolytes containing polyvalent ions, e.g., LaCl_3 , $\text{La}_2(\text{SO}_4)_3$, and $\text{La}(\text{Fe}(\text{CN})_6)$.

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EDWARD L. BOWLES, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Ultrahigh-frequency research and technique

Through the application of funds made available by the Carnegie Institution of Washington to the Massachusetts Institute of Technology, an extensive microwave program has been made possible. This program was carried out during the Institute's fiscal year July 1, 1940 to June 30, 1941.

The program had two related objectives: (1) basic research, and (2) instruction of advanced students in the theory of and techniques applicable to radio waves in the region principally from 10 centimeters down to 1 centimeter.

At the outset it was felt that the Institute's past background of research in the ultrahigh-frequency fields could best be put to use by continuing the several problems in hand and using the research group to train new men in the applications for possible use in the emergency.

A research was carried on on the propagation of waves in the region of 10 to 1 centimeter, in which Professor J. A. Stratton carried out significant work on the effect of atmospheric turbulence.

A second aspect of the research treated the theory of directive radiating systems,

with particular emphasis on compactness and high-beam concentration. This included theoretical and experimental analyses of wave guide, resonant, and reflector types of radiators. Dr. L. J. Chu conducted this work in pre-eminent fashion.

A third aspect of the work was in effect a continuation in the design and study of magnetron generators for application to measurements on dielectrics in the range of from 10 to 1 centimeter.

The fourth and final aspect of the program contemplated an investigation of the behavior of plasma in ultrahigh-frequency fields. This last program had barely got under way when emergency national defense problems resulted in its being held in abeyance.

The complementary program relating to advanced instruction in the field of this range of wave lengths involved the development of convenient laboratory power sources (oscillators) and of calibrated measuring means. Through the establishment of this broad program an unusually competent staff of junior and senior research men was gathered together.

JOSEPH C. BOYCE, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Research in the spectroscopy of the vacuum ultraviolet. (For previous reports see Year Books Nos. 38 and 39.)

The program of mapping the spectra of the elements in the vacuum ultraviolet has gone forward. The collection of spectra of sparks in an atmosphere of nitrogen is substantially complete and a satisfactory start has been made on spectra of metallic arcs. The parallel Works Progress Administration project for the measurement of the plates continued in operation until late in June. Wave-length lists for several spectra have been placed in the hands of other investigators for term analysis.

During the year covered by this report, 191 spectrograms have been made, with various exposure times and with and without wave-length standards, distributed among the following 21 elements: magnesium, silicon, vanadium, chromium, manganese, nickel, zinc, columbium, molybdenum, palladium, cadmium, tin, antimony, iodine, tantalum, osmium, iridium, thallium, lead, bismuth, and uranium. Spectrograms made included 8 more elements—sulphur, chlorine, calcium, gallium, germanium, indium, hafnium, and rhenium—but for various reasons, such as insufficient variety of exposure time or insufficient wave-length standards, additional spectrograms may be necessary before these elements can be considered as completed. This is all in addition to the 12 elements reported last year.

All these spectra have been made from sparks in an atmosphere of nitrogen, an excitation which favors the second and third spectra of the elements. Additional experiments have still failed to excite the spectra of the rare earths in this type of light source. It may be that the second spectra of these elements contain no strong lines in the region of the vacuum ultraviolet and that the energy available in the

spark is insufficient to excite the third spectra. This explanation is possible but not conclusive, and further methods will be tried.

Apart from the rare earths, certain light elements of which the spectra have already been adequately measured by other investigators, and the elements of strong radioactivity which are not proposed for investigation, this substantially completes the collection of spectra which can be obtained from sparks in nitrogen.

Our attention now turns to arcs in nitrogen or in helium, which will give the first and second spectra of the elements. Preliminary exposures made in June have tested the operation of the arc holder and have given information about exposure times.

In the year and a half of the operation of the W.P.A. project, 106 exposures including 23 elements have been measured on the Harrison automatic comparator. This instrument gives a permanent record on a strip of motion-picture film, showing the exact profile of all the lines on the plate and a photograph of the wave-length dial reading for each line. Six such records for each exposure are read by the W.P.A. workers, recorded on cards, and averaged. The recording has now been complete for some 60 exposures. These data still require checking and editing, and a special assistant has been engaged for the summer to expedite this work.

Cobalt data have now been sent to the Princeton Observatory. One investigator in this laboratory, to whom the rhodium data were turned over a year ago, reports satisfactory progress in his term analysis. Data on titanium and ruthenium have

been turned over to two other investigators in this laboratory.

In the course of editing these data a need was found for a provisional table of impurity lines. Such a table has now been prepared, including, in order of wave length, about 6000 lines between λ_{2000} and λ_{300} . These were selected from published lists of the first five spectra of the seventy elements on which any data are available in the literature. Mimeographed copies of this provisional impurity list have been prepared for distribution to other laboratories working in this field.

In the general reduction of W.P.A. projects which occurred late in June, our parallel project for the measurement of the plates was discontinued. The only loss is a delay in the availability, in a convenient form, of the data contained in exposures

not yet measured. Data now available as a result of this project are probably sufficient to meet the immediate needs of those few spectroscopists who have not been temporarily diverted to other matters.

Miss Pauline Pitkin has continued as research assistant in the operation of the spectrograph. Mrs. J. T. Moore has done part-time work in the preparation of the identification list. Mrs. E. R. Lyman has been engaged as a temporary additional assistant for the summer months of 1941.

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WALTER H. NEWHOUSE, Massachusetts Institute of Technology, Cambridge, Massachusetts. *Spectrographic studies of minor elements in minerals*

The analyses were made on a 21-foot, 30,000-line grating spectrograph in Wadsworth mount, which covers a range of 3500 Å, between 2500 and 6000 Å. The part of the spectrum chiefly used in this work is from 2830 to 4630 Å. The analytical work was done by R. F. Jarrell and Albert Jehle.

Variations within single crystals. Work was completed on the variation of minor elements in single crystals of galena (PbS) and calcite ($CaCO_3$). In cooperation with Dr. Clifford Frondel and R. F. Jarrell, it has been established that the minor foreign elements are not uniformly distributed through the host crystal. Regions of foreign-element concentration are related to the growth surfaces of the crystal and fall into two types, one of which consists of pyramidal regions subjacent to the faces of one form on crystals bounded by several

different forms, the other of alternating bands parallel to the growth surfaces without selectivity as to crystal form.

Cubo-octahedrons of galena were found to contain silver and silicon approximately ten times more abundantly in the growth regions subjacent to the octahedral faces than in the regions subjacent to the cube faces. These variations are considered to arise from the unequal adsorptive capacity of the different forms for these elements during the growth of the crystal. The elements copper, iron, aluminium, chromium, barium, strontium, calcium, and magnesium show no marked variation with respect to the morphology of the galena crystals.

In the calcite crystals, compositional variations were found in the successive growth zones. No special concentration of minor elements was found to be related to the

morphology in the case of any of the minor elements found (copper, iron, aluminium, strontium, magnesium, manganese).

Variations of minor elements in mineral deposits. The minerals in four different types of deposit have been hand-picked and are being spectrographically examined to determine the variations displayed by (*a*) the different minerals, (*b*) the same minerals from different deposits, (*c*) deposits closely associated with different kinds of intrusive igneous rock.

The chief minerals in the four types of deposit show significant variations in minor-element content, evidently related to the geological association of the type of deposit.

The mineralizations being studied include: (1) magnetite-silicate deposits in limestone near diabase or other ferromagnesian-rich intrusive rock; (2) magnetite-silicate deposits in limestone near granitic pegmatite; (3) magnetite-silicate deposits in gneiss near granitic pegmatite; (4) sphalerite-silicate deposits in limestone or dolomite near granitic pegmatite; in these deposits some lead is present as galena.

Routine qualitative examination with estimation of relative proportions present has been made on most of the minerals for approximately fifty elements. Photometric measurement of line intensities was made on magnetite from two types of deposit in order to obtain a more exact comparison of significant elements. Quantitative work has been completed on the significant elements cobalt, nickel, titanium, manganese, zinc, silver, and copper in pyrite from these deposits.

It is found that the kind and proportions of minor foreign elements in a mineral are usually characteristic for the type of deposit. The proportions of minor elements differ in each of the several minerals of a deposit. The results to date indicate that if a graphic representation is made of the

kind and proportions of minor elements in each of the several minerals of a deposit, a unique or nearly unique pattern results. In a single deposit or within a type of deposit the minor foreign elements present in one mineral are usually, but not always, present in detectable amounts in the other minerals of the aggregate.

In the deposits mentioned under the first type, those associated with diabase or other ferromagnesian-rich intrusive rocks, the pyrite contains an especially high percentage of cobalt, 1 per cent or more, and nickel, 1 per cent or less; also manganese and titanium are relatively higher and zinc lower than in the pyrite from the other types of deposit. The magnetite from this first-mentioned group contains magnesium, cobalt, nickel, vanadium, and strontium in proportions higher than in the magnetite from the other types of deposit. Zinc and scandium were not detected in the magnetite from this group, although both are present in the magnetites associated with granitic pegmatites. The significant elements present in the deposits associated with the granitic pegmatites include beryllium sporadically distributed in the zinc deposits. Yttrium, zirconium, molybdenum, lead, and silver are widespread in the silicates of the zinc deposits, and barium is relatively high in some of the silicates.

Areal variation of minor foreign elements in the magnetite-silicate deposits in gneiss with associated pegmatites in the New Jersey highlands and contiguous parts of Pennsylvania and southeastern New York. The magnetite from approximately fifty deposits in the gneisses is found on examination to contain more cobalt, nickel, vanadium, and strontium in the northern part of the area than in the southern part; scandium and chromium are more abundant in magnetite from the southern part.

In the early iron-mining in this region it was known that the ores in the southern

part of the area were of Bessemer type owing to low phosphorus content, whereas those in the north contained enough more phosphorus to make them non-Bessemer. This condition is doubtless caused by a variation in the percentage of apatite in the ores. Other minerals appear to vary in proportion similarly. Work done in our laboratory indicates that solid solutions may display changes in composition which register geological changes too small to be registered by addition or subtraction of a mineral species. Since in this area there is apparently a variation in the proportions of mineral species, the variation in composition of the magnetite was to be expected.

Changes in wall rocks. The "crystalline limestones" forming the wall rocks of two of the sphalerite-silicate deposits were sampled and analyzed to determine what elements were added or subtracted during mineral introduction. The available rock exposures, although not sufficient to give perfect sets of samples for this purpose, yielded material that furnished much information.

The coarsely crystalline carbonate rocks were crushed and cleavage fragments picked under the microscope. Numerous pickings were made to check results.

At a prospect near Long Lake, Ontario, the crystalline limestone within a few feet of the sphalerite-silicate mineralization contained more lanthanum, lead, and manganese and less magnesium than was found in samples taken 150 feet away. Barium, strontium, and yttrium were erratic

in distribution. Similarly, at a prospect containing a sphalerite-silicate mineralization near Sylvia Lake, New York, more abundant lead and manganese were found in the dolomite cleavage fragments within a few feet of the mineralization than were found in similar fragments from rock a mile or more away. Lanthanum and yttrium were not detected in the dolomite rocks at this place. Barium and strontium were erratic in distribution.

Minor elements in the granitic pegmatites associated with the mineralizations. Of particular interest is the relatively high percentage of lead present in some of the feldspars of the pegmatites most closely associated with the sphalerite-silicate mineralizations. Further work must be done on these feldspars to eliminate the possibility of salting.

The micas present in these pegmatites more frequently contain beryllium, manganese, and tin, and less frequently lead, molybdenum, scandium, silver, and yttrium than do the micas from the sphalerite-silicate mineralizations. Less barium and vanadium are present in the micas from the pegmatites.

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FRANK A. PERRET, New York, New York.
(For previous reports see Year Books Nos. 38 and 39.)

Continuation of this work has consisted mainly in the preparation, to near completion, of a fourth volume, dealing with Mr. Perret's observations during the past forty years. The writing of the text has

developed into a quite special revelation of the breadth of this science by bringing out more fully its direct contacts with other branches, such as meteorology and the development of electrical potential, as

well as the more obvious thermodynamic, chemical, and general geophysical manifestations. All this has required reference, correspondence, etc., much hampered by world conditions.

Considerable field work has been carried on, made possible by the permission of the governments concerned. A further study was made, with photographic documentation, of the little-known Qualibou soufrière at St. Lucia. At Martinique, aerial photography of some features at the summit of Mount Pelée has so far been prevented by weather conditions.

An event occurring four years ago, but recently consummated, should be recorded here. On the occasion of his seventieth birthday, St.-Pierre, Martinique, conferred honorary citizenship upon Mr. Perret, who had seen the city through the three years of the second Pelée eruption, and there founded the Volcano Museum and Research Center. A very beautiful diploma, the work of a local artist, commemorates the event, and points out that he is the second American to be thus honored—the first being Theodore Roosevelt, for relief sent during the 1902 eruption.

DIVISION OF PLANT BIOLOGY

Central Laboratory located at Stanford University, California

H. A. SPOEHR, *Chairman*

During the past two years a number of important experimental observations on the process of photosynthesis have been made which are of such fundamental significance that virtually all hypotheses thus far advanced to account for the mechanism of the process must be abandoned or drastically revised. These results have emanated from various laboratories, so that some of the most important conclusions have been confirmed by different investigators using their own distinct methods. These recent findings, besides revealing the inadequacy of existing hypotheses, have served to emphasize the necessity of obtaining fuller and more precise information concerning the chemistry of the products formed in photosynthesis. It is obviously impossible to develop rational theoretical views regarding intermediate chemical steps and products as long as uncertainty exists concerning the end products of the photosynthetic reactions. Among the results of recent researches which have so profoundly affected our thinking on the mechanism of photosynthesis may be mentioned: (1) the redetermination of the efficiency or quantum yield of the process; (2) confirmation of the variability of the photosynthetic quotient, i.e., the ratio of the volume of carbon dioxide absorbed to that of oxygen liberated; and (3) the observation of the fact that many living cells have the power of reducing carbon dioxide in the dark, or at least of incorporating carbon dioxide into pre-existing organic compounds. The results obtained from these researches have materially altered the basic concepts of the nature of the reactions which are involved in the photosynthetic process, and, as has been stated, they

have shattered our hypotheses of the chemical mechanism.

The significant outcome of all this effort is, however, definitely in the direction of progress. A basic maxim of science is that truth comes out of error more easily than out of confusion. Hypotheses constitute efforts toward the orderly arrangement of observed facts. These facts have been materially altered and extended. They must again be arranged and correlated to form an ordered hypothesis. And in this process of correlation important gaps in our knowledge have become evident, which can be filled only by further experimental investigation.

Measurements of the efficiency of photosynthesis have been completed and have shown the quantum yield to be $1/10$ to $1/12$ instead of $1/4$, the value which had been accepted for the past twenty years. This lower value receives considerable support from the fact that it has now been confirmed by three groups of investigators working independently. In the course of the investigations on the quantum efficiency of photosynthesis a number of important related facts were uncovered concerning the course of the reaction and the factors which influence this. These pertain to the possible role in the photosynthetic process of other pigments besides chlorophyll and to the influence of light on the respiratory processes. Although at present these observations tend to complicate our concept of the process considerably, it is believed that further elaboration of these relationships will aid in a clarification of what actually occurs in the living plant during photosynthesis.

It is an impressive commentary on the

difficulties inherent in this subject that no definite results have come from over fifty years of effort to determine by means of chemical analysis the precise nature of the products formed in photosynthesis. Not only do we not know what are the intermediate products between carbon dioxide and carbohydrate, for example, but we are not even certain as to what percentage of the carbon dioxide taken up by the plant in photosynthesis is converted into carbohydrate. The vast array of proximate analyses of leaf material indicates that some form of carbohydrate is the major product of photosynthesis, and this also seems probable from a cursory examination of vegetable material. It is a matter of general knowledge, however, that different genera and families of plants differ greatly in their chemical composition, and this seems to be particularly true of the photosynthetic organs, where the products of photosynthesis are to be found. Yet no thoroughly reliable chemical analyses have been made in conjunction with determinations of photosynthesis so as to follow through the fate of the carbon dioxide which is absorbed by the plant. Nor are there sufficiently exhaustive chemical analyses even of the species of plants which are now commonly used for photosynthetic measurements. This state of affairs has its explanation in a variety of technical difficulties connected with the culturing and chemical analysis of the organisms in question. It nevertheless constitutes a serious gap in our knowledge, which must be filled if rational hypotheses are to be formulated concerning the mechanism of photosynthesis in the organisms being subjected to intensive study.

Several methods of approach to this problem are now being followed, as no single one seems entirely adequate in itself. Of these the following may be cited: First, certain diatoms which appear to be rather

aberrant in the compounds formed by their photosynthesis are being used as material for photosynthetic measurements, and at the same time are cultured in sufficient quantity so that they can be subjected to analysis of their pigment complex and of the products synthesized. These investigations are designed to determine a number of facts which are fundamental for the formulation of a rational concept of the chemical mechanism of photosynthesis. Second, the use of radioactive carbon, as has been mentioned in an earlier report, provides a splendid means of following the fate of the carbon dioxide from the moment it is absorbed by the plant through its elaboration into organic compounds by the photosynthetic process. The recently discovered isotope of carbon, C¹⁴, will prove to have many advantages for the prosecution of these researches. This method is being used on a typical higher plant, and photosynthesis measurements are being conducted in conjunction with the chemical analysis of the products. It has already become evident that existing methods of analysis must be refined in order to apply these to the various categories of compounds which must be considered. During the past year special attention has been devoted to the isolation of different categories of compounds from leaves and to a study of the enzyme systems which produce alterations in these components. Finally, the culture of albino, or chlorophyll-free, plants has been further developed with a view to determining what particular compounds are essential to the nutrition and development of the plant.

The investigations in experimental taxonomy are approaching another node as the analysis of plant relationships is advanced and coordinated. Four distinct lines of approach have been brought to bear on

the evolutionary problems in the Madiinae. These are the morphologic, geographic-ecologic, genetic, and cytologic methods. The resulting evidence is now being analyzed and coordinated, and a clear, dynamic picture of relationships is unfolding for this subtribe of the sunflower family.

Particular attention has been given during the past year to the genetical and cytological situations in *Layia*, so that the interrelationships within that genus of fourteen species are now understood. This is probably the most comprehensive picture of relationships in a representative genus of plants yet obtained. Many data in a somewhat less advanced state of analysis are also on hand for the five other large genera of the Madiinae.

Of particular interest is the manner in which the lines of evidence from the different viewpoints supplement one another and emphasize different aspects when brought to bear on the same materials. Morphology, which is the basis of classic taxonomy, is useful in finding markers for identifying the natural units discovered by genetic and cytologic evidence. Boundaries of species determined by classic taxonomic methods often coincide with those disclosed by cytogenetic data, but in other cases there is no agreement. The study of geographical and ecological distribution gives clues to plant relationships when used in connection with other studies.

Genetical methods, which test the fertility of hybrids and the vigor of their second-generation offspring, prove to be precise indicators of relationship. All stages of genetic relationship, as shown by a decreasing scale of fertility and vigor in hybrids, are found in different groups in *Layia*. Cytological studies serve to determine not only the chromosome numbers, but also the degree of pairing of the chromosomes in hybrids. The interpretations from this evidence often coincide with the

results from genetic experiments. On the other hand, chromosome pairing, which is probably an indicator of relationships of a higher order, is not so sensitive an indicator as genetic tests. For example, chromosomes may show little or no pairing in certain sterile hybrids, while in others just as sterile they pair normally.

It has been found that certain species which are separated by only partial genetic barriers may be grouped together into species complexes. By contrast, other species are genetically isolated, and exist as monotypic entities showing little variation. Since cytological boundaries, as determined by lack of pairing in hybrids between species, are more inclusive in *Layia* than the genetic boundaries outlining complexes of species, it is thought that the cytological evidence points out the broader evolutionary lines in the genus.

Brought together, all the evidence from the genus *Layia* leads to a mosaic picture of relationships between the component species. The patterns of this picture harmonize, because none of the findings are antagonistic to established facts in morphology, ecology, genetics, or cytology. Yet the pattern is so intricate that evidence based on one approach alone leads to a rudimentary concept of speciation as compared with the picture obtained by using all four lines of evidence.

A goal long sought by experimental biologists has been the artificial synthesis of existing wild species. Definite progress toward this goal has been made during the past year. An undescribed species of *Madia* from northern California, with the highest chromosome number known in the Madiinae, 24 pairs, grows in an area near its supposed progenitors, which have 16 and 8 pairs of chromosomes, respectively. A single artificial hybrid obtained between the suspected parents of the new species yielded 46 plants, each with approximately

48 somatic chromosomes. These plants match the new species very closely.

The work at the field stations has centered around the selection experiment, and the assembly of materials of *Achillea* and *Potentilla* for a future intensive study of climatic races.

The conditions which determine the types of vegetation found growing naturally in uncultivated areas are numerous and complex. What these conditions are and the manner in which they operate, singly and collectively, may be investigated in two ways. One involves physiological experimentation with plants and instrumental study of the fluctuating environment over long periods. The other involves knowledge of the distribution, habitat requirements, seasonal behavior, and social features of the plants, comparing the findings in one place with those in another, and correlating the findings with as much as may be readily learned about the environment. During the course of desert investigation both of these methods have been used. For the current work, in which preliminary study is being given to large areas, the geographical viewpoint of the latter method has been chiefly employed. Through it may be secured the facts of the role of plants in nature. By it are suggested also many problems for future attack which would involve prolonged instrumentation and experimentation for their solution. The questions of interpretation that are involved are equally difficult with either method. In the regional investigation of the North American Desert, the effectiveness of the geographical method is greatly enhanced by the broad background of detailed work on desert plants and desert conditions that was accumulated during the operation of the Desert Laboratory.

Paleobotany provides a historical viewpoint for botany. Angiosperms and conifers, abundantly represented in the fossil record and closely similar to plants now living, furnish a basis for the reconstruction of many forests of later geologic time. Early centers of distribution and subsequent routes of migration are indicated by the loci of their successive appearances in rocks of known age. Climatic trends may be outlined from a study of their environmental requirements, as judged from the habitats of related living trees. Some of the details of Tertiary landscapes may be restored from analysis of the relative abundance of fossil species whose modern equivalents show a definite response to topography.

All these considerations, significant to the student of earth history, have the additional value of contributing to the explanation of many problems of modern plant distribution. For without some idea of the characteristics and ranges of the maples, oaks, pines, and redwoods of the past, there is only a partial basis for interpreting their present geographic occurrence. Current studies of the Mascall and related floras of the Columbia Plateau, involving study of a large number of well preserved fossil leaves and fruits, are adding to our knowledge of one of the richest and most widely distributed forests of the Tertiary period. Elements now widely scattered throughout the northern hemisphere were living together during the Miocene epoch in eastern Oregon and adjacent areas. Their subsequent restriction to China, the eastern United States, and other areas far removed from the Columbia Plateau raises questions whose answers will give us a broader basis for understanding the continuing response of vegetation to a changing earth.

Since 1914 the Carnegie Institution of Washington has been giving support for

the developmental study of vegetation under the direction of Dr. Frederic E. Clements. In a long series of investigations, devoted primarily to the western areas of the United States, Dr. Clements has evolved fundamental concepts of the origin, growth, maintenance, and extinction of many vegetative units and climax formations. The almost inextricably interwoven influences, physiographic, climatic, and purely biological, which determine the movements, development, and disappearance of vegetative units have been analyzed and classified. From these investigations has arisen the school of dynamic ecology.

These investigations, which had their inception many years before the Carnegie Institution of Washington lent its support, had their roots in the era of land exploitation in the Great Plains region. During the periods of economic boom and tragic

depression which have marked the history of this region, the investigations of the scientific principles which underlie the use of these land areas for the production of the nation's food have been continued and extended. The basic conclusions emanating from these studies have by small degrees permeated governmental bodies. The pioneer attitude that Nature can at will be shaped to man's convenience is gradually giving way, where living organisms are concerned, to a concept which recognizes the inflexible demands of Nature and strives to understand the interdependence between man, the soil, the plant, and the sun as it comes to expression in the myriad of phenomena observable in organic nature. In the development and dissemination of these basic concepts the school of dynamic ecology has indeed met Francis Bacon's criterion that "All knowledge should be referred to use and action."

BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, AND H. W. MILNER

ORGANIC NUTRITION OF PLANTS

The experiments on the artificial nutrition of albino maize plants which were mentioned in the report of last year (Year Book No. 39) have been repeated under a variety of conditions. There is considerable variability in the vigor of individual albino plants. As a consequence, whereas some plants can be kept alive through artificial nutrition for 4 to 5 months and during this time produce rudimentary ears, other plants raised from the same lot of seed and under identical conditions languish and die after a few weeks. The causes for this unpredictable difference in vigor are as yet quite obscure.

In the endeavor to determine the most favorable conditions for the culture of albino plants through artificial nutrition, it

has been found that the light factor is of much significance. Albino plants were grown under three sets of light conditions: in the greenhouse, in diffuse north light, and in the dark. The temperatures ranged from 18 to 25° C., the plants growing in mineral nutrient solution and in sand culture. The dark series were not in complete darkness, about $\frac{1}{2}$ hour every day being required to replace the organic nutrient solutions under the weakest light possible. This light intensity was not sufficient to maintain or to produce chlorophyll in normal etiolated maize plants.

The difference in rate of growth and in form of the albino plants grown in these three light intensities was striking. The plants grown in the greenhouse were quite dwarfed, attaining a height of not over

6 inches, although 10 to 15 leaves were formed. Most of these plants died before forming any rudimentary ears. Addition of indolylacetic acid to the organic nutrient solution fed the plants produced no favorable growth effects. In contrast with this typical dwarfing effect of light, the albino plants grown in the dark showed the elongation of "etiolation," long, slender leaves and narrow stems. But these plants remained alive over 4 months and produced rudimentary ears.

At the same time normal, green plants were grown alongside the albinos and were also kept alive by artificial organic nutrition. The leaves of these plants soon lost their chlorophyll and the new leaves which were formed were chlorophyll-free. In appearance they were soon identical with the albinos in size and form. After having been in the dark for 125 days, all the plants were exposed to the light of 250-watt Mazda lamps. This treatment produced chlorophyll in the originally green plants within a few hours, but the albinos showed no change of color.

For purposes of culturing albino plants by means of artificial organic nutrition, the best results were obtained under diffuse-light conditions. The plants were sturdier, they had broader leaves, and there was a larger number of survivors. For nutritional studies, therefore, these conditions are most favorable. It is conceivable that the complex effects of light on growth can be investigated to advantage by means of albino plants artificially nourished, for under these conditions there is no question of complications arising from the photosynthetic activity, such as exists in normal green plants. Various modifications of standard mineral nutrient solutions have been tried without producing any significant effects. For example, no significant differences were observed between albino

plants which received their nitrogen as nitrate and as ammonium ion.

To date all that can be said is that albino maize plants can be kept alive by artificial organic nutrition for extended periods of time representing about the normal life span of the chlorophyllous plant, and that under these conditions the albinos produce the same number of leaves and small ears. No staminate inflorescences have yet been produced, although a wide variety of hormones and vitamin preparations have been added to the organic nutrient. The gain in dry weight of the albinos thus nourished is very small as compared with that of the plants which derive their organic food through photosynthesis. The best results in the culture of albino plants have been obtained with sucrose as the organic nutrient. If sucrose or some other simple carbohydrate is the only product of photosynthesis, it may be possible to attain the development of a complete albino plant by artificial nutrition with this carbohydrate. On the other hand, if, as now seems highly probable, the photosynthetic process produces other essential substances, even in only very small amounts, it may be possible to determine this fact by a process of trial and error through the feeding of a wide variety of organic compounds. Laborious as such a process of trial and error in nutrition experiments would be, it may prove to be more exact than the employment of chemical analysis. Over fifty years of effort to determine the exact nature of the products of photosynthesis by means of painstaking chemical analysis have yielded very little beyond proximate results.

THE USE OF RADIOACTIVE CARBON DIOXIDE IN PHOTOSYNTHESIS

The mechanism whereby sunflower leaves absorb carbon dioxide from the

atmosphere has already been reported on from this laboratory. Radioactive carbon proved to be of considerable value in distinguishing several of the component reactions. There is every indication that the use of radioactive carbon will greatly facilitate the further tracing of the transformations of carbon compounds within the leaf.

The radioactive carbon, C¹¹, used in the previous tracer experiments loses half of its radioactivity every 20.35 minutes. For this reason it is impossible with this isotope to carry out experiments of long duration. A radioactive carbon, C¹⁴, with a half life of hundreds of years has recently been prepared. The use of this isotope opens up new possibilities for tracing the carbon through its various transformations within the plant. Because of the weakness of the radiation emitted by this heavier isotope, methods for its detection and estimation, different from those used for the estimation of C¹¹, had to be developed. As there is assurance that this new isotope will become available for future work, it was necessary to develop methods and apparatus for its use in this connection.

One of these developments is an apparatus for measuring the carbon dioxide absorbed in photosynthesis. The arrangement is such that a known quantity of carbon dioxide can be introduced into a closed system, containing the photosynthesizing leaf, and circulated until most of the carbon dioxide has been absorbed by the leaf. The uptake of carbon dioxide can be continuously and quantitatively measured by means of a glass-electrode assembly. Such an arrangement is well adapted for economical use of the radioactive carbon dioxide.

For tracing the radioactive carbon among the constituents of the leaf, methods have been devised for segregating various categories of compounds from the leaf and for recovering quantitatively the carbon con-

tained therein as carbon dioxide. This carbon dioxide can be transferred to an ionization chamber and the radioactivity measured by means of an electrometer. An ionization chamber-electrometer assembly suitable for this purpose has been constructed during the past year.

During the development of the apparatus and methods just mentioned, it has been possible, using sunflower leaves, to obtain information concerning the increase in amounts of certain carbohydrate fractions as related to the carbon absorbed in photosynthesis. A detailed analysis must await the accumulation of further data, but the results obtained thus far indicate that in photosynthesis a significant amount of material besides carbohydrate is formed from the carbon dioxide absorbed. In the carbohydrate category the greatest increase occurred in the starch fraction, next in the disaccharide fraction, and least in the monosaccharide fraction. There is probably little change in the carbon content of the residue left after removal of the starch by hydrolysis.

The following is a brief outline of the method used: A sunflower leaf, starved by storage in the dark, was cut into two portions. One portion was prepared immediately for analysis; the other was placed in a chamber containing a known amount of carbon dioxide, and illuminated. By circulating the gas through an electromotive force cell containing a solution of bicarbonate ion, the uptake of carbon dioxide was followed continuously. When the desired amount of carbon dioxide had been absorbed, the half leaf was removed and prepared for analysis.

For analysis the two portions of the leaf were treated by as nearly identical procedures as possible. They were extracted with 80 per cent ethyl alcohol to obtain the monosaccharides and disaccharides. The leaf residue was then heated with dilute

hydrochloric acid to hydrolyze the starch and remove the resulting glucose. Aliquot portions of the extracts were analyzed for sugars and also for total extracted carbon by wet combustion. The increase produced by illumination was determined by comparison of the analytical results obtained on the illuminated and the unilluminated portions of the leaf. The uptake in carbon was not wholly accounted for by the increase in carbohydrates as determined by the analytical procedures employed.

For certain determinations with radioactive carbon it will be necessary to isolate the sugars quantitatively in the form of known compounds. From experience it is known that sugars formed in photosynthesis can be converted principally into glucose and fructose. A reagent which will precipitate these two sugars quantitatively will be of considerable value. It has been known for many years that phenylhydrazine reacts with these sugars to form a quite insoluble compound, phenylglucosazone. In spite of the fact that phenylglucosazone is insoluble, the reaction between glucose and phenylhydrazine does not yield a quantitative precipitation of the osazone. It seemed worth while, however, to investigate the conditions for the formation of this derivative, in the hope that conditions might be found which would give almost, if not quite, complete precipitation. Investigation of this reaction has demonstrated that it is complicated by simultaneous side reactions which use up part of the glucose, and that the incompleteness of the precipitation is not due to the solubility of the osazone in the reaction mixture. Thus far no conditions have been found for obtaining a complete recovery of the glucose in the form of an osazone.

THE STATE OF PIGMENTS IN LEAVES

Investigations of the properties of the pigments in leaves have thrown consider-

able light on the applicability of several new theories regarding the photosynthetic process. These studies had as a primary objective the determination and comparison of the spectral absorption properties of the carotenoid and chlorophyll pigments extracted from green cells by organic solvents and by various aqueous dispersing agents. This information, in connection with studies of the efficiency of photosynthesis at various wave lengths of light, has provided a basis for estimation of the photochemical activity of the pigments in the living cells, as described in another section of this report by Drs. R. Emerson and C. M. Lewis.

In addition to the work on green plants, the pigments of a blue-green alga, *Chroococcus*, were extracted and their spectral absorption properties were determined. The green pigment consisted entirely of chlorophyll *a*. The yellow pigments, isolated in small quantities, were different from those of the common green plants. A blue pigment, insoluble in organic solvents but soluble in water, was found and was shown by the spectral absorption measurements to be identical with a blue pigment isolated by other workers from another blue-green alga, *Aphenizomenon flos-aquae*. This pigment is intimately associated with protein, from which it could not be separated without decomposition.

In the cells of the *Chroococcus*, the pigments are not concentrated into visible bodies as they are in the cells of the higher green plants. When *Chroococcus* cells were ruptured by grinding in a mortar with water and silicon carbide and the mixture was centrifuged, a suspension containing blue, green, and yellow pigments was obtained. In this solution, the blue pigment was not bound to the green pigment, since the two could be separated by precipitation with ammonium sulfate or by adsorption on a column of starch. Indica-

tion that this separation was not made possible by preliminary splitting of a large protein-pigment complex by autolysis was obtained by extracting the cells at 0° C., separating the pigments at this temperature.

The intimate association of pigments with protein in the living cell suggests that the proteins may be of importance in the transfer and utilization of light energy by the plant. Whether this involves only the orientation of the pigments in the cell or other more complex and less obvious functions must be established by further investigations.

ISOMERIZATION OF CAROTENOID PIGMENTS AND OLEFINIC FATTY ACIDS

Several natural unsaturated or olefinic fatty acids contain systems of alternate single and double bonds like the conjugated systems found in the yellow, carotenoid pigments. In an attempt to interpret some of the chemical and biochemical transformations of these so-called polyenes, the effects of a number of catalysts on the isomerization of olefinic acids and of carotenoid pigments have been compared.

Under the same conditions, fatty acids like *alpha*-licanic and *alpha*-eleostearic, each with three conjugated double bonds, undergo changes in their spatial arrangement about the unsaturated linkages more readily than does oleic acid, which has a single double bond. Carotenoids, particularly xanthophylls, with ten and eleven conjugated double bonds, can be isomerized into at least two different groups of pigments, depending on the catalysts and conditions that are employed. By the action of heat or of iodine in the presence of organic bases such as pyridine or dimethyl-aniline, isomerization proceeds to an equilibrium between the original pigment and two or three isomers that are strongly ad-

sorbed on columns of specially prepared magnesia. With iodine alone, with halogen acids, or with a variety of natural organic acids, carotenoids in solution are converted into a series of pigments that are very weakly adsorbed on magnesia. This type of reaction results in rather rapid decomposition of all the original carotenoid. It occurs more easily with xanthophylls than with the hydrocarbon carotenes. There is some indication that with the xanthophylls it may involve changes in the spatial relations of the hydroxyl groups.

Determination of the conditions under which the isomerization takes place, and the subsequent development of procedures to avoid these reactions, have been of practical significance to investigators concerned with the preparation of carotenoids from various plant products. Prevention of the isomerization of carotenoids during their extraction from sources rich in free organic acids may be accomplished by the addition of organic bases like pyridine or dimethyl-aniline to the solutions and by maintenance of the solutions at low temperatures.

From a biochemical point of view, the spatial configuration of olefinic molecules ranks in importance with the well established spatial relations of the optically isomeric compounds. In the case of the leaf carotenoids, natural synthesis yields only one of several easily formed isomers. Presumably, this selective synthesis depends on the specific action of enzymes contained in the cell. It controls the development and maintenance of at least a part of the photosynthetic apparatus of the plant.

OXIDATION-REDUCTION REACTIONS IN LEAVES

Photosynthesis in green plants may be regarded as the difference between the reduction reactions that take place under the influence of light and the oxidation reactions essential to the maintenance of

the life of the cell. Thus far, few reduction reactions in green plants have been amenable to biochemical attack. Oxidation reactions, on the other hand, have been found to take a variety of courses, and it has been possible to detect some of the catalysts or enzymes that promote them. One such enzyme is the ascorbic acid oxidase that facilitates removal of hydrogen by oxygen from the strongly reducing vitamin C. Enzymes that catalyze this reaction have now been found in nearly all plants showing rapid respiratory or oxidative capacity.

When leaves are placed in the dark at 20° C., the ascorbic acid content decreases rapidly. This indicates that ascorbic acid plays a part in the metabolism of the leaf. When these leaves are placed in the light a second time, the ascorbic acid increases. From a study of the rate of increase of the ascorbic acid some evidence may be obtained regarding the mechanism of the synthesis of this unique plant product.

In many plants, such as horse-bean seedlings (*Vicia faba*), higher concentrations of ascorbic acid have been found in the growing tips than in the mature leaves. When the plants are placed in the dark, the ascorbic acid decreases more slowly in the tips than in the older leaves. It remains to be established whether the acid migrates to the tips or is synthesized there.

In addition to the specific oxidation reactions that are catalyzed by the enzymes of leaves, a number of unspecific oxidative processes have been observed in plant material killed under conditions not destructive to enzymes. Some of these oxidative processes result in the destruction of vitamins of color and of other components of vegetable tissue, and these processes are of considerable importance in the loss of flavor and in the deterioration of vegetable food products. As the result of further work on the oxidative systems of plants, it now appears that many of the destructive reac-

tions may result from secondary transformations initiated by highly specific enzymatic oxidations. For example, in last year's annual report an enzyme system extracted from legume seeds was shown to catalyze oxidation of unsaturated fats but not oxidation of other closely related unsaturated compounds, such as the carotenoid pigments of green leaves. If carotenoids were added to both fat and enzyme, these yellow pigments were then oxidized rapidly. Further study has revealed that this fat and enzyme system can oxidize a variety of other compounds, such as ascorbic acid and the polyphenols. It converts *p*-phenylenediamine into a deep blue oxidation product, a reaction that is likewise accelerated by the enzyme cytochrome. It transforms dihydroxyphenylalanine, an amino acid found in the leaves of several plants, into the well known black pigment melanin. Unless special precautions are taken, this fat-oxidase system may be confused with the specialized enzymes that oxidize polyphenols, ascorbic acid, and *p*-phenylenediamine, or with those that form melanin from tyrosine or dihydroxyphenylalanine.

Oxidation of various compounds by the system of unsaturated fat, fat oxidase, and oxygen has been found to take at least two different courses. Oxidation of the carotenoids depends on concomitant oxidation of fat. Peroxides of the fats formed by the action of the enzyme are without effect on the yellow pigments. Oxidation of polyphenols, *p*-phenylenediamine, and ascorbic acid by the fat and enzyme is caused by reaction of the peroxides of the fat and does not depend on concomitant oxidation of fat.

Polyphenols have a pronounced effect on the oxidation of fat by the enzyme from legumes, and on the oxidation of other compounds by the system of fat plus enzyme. Absorption of oxygen by unsatu-

rated fat in the presence of the enzyme is inhibited by hydroquinone and catechol. It is scarcely affected by phloroglucinol and resorcinol. Each of these four polyphenols inhibits the oxidation of *p*-phenylenediamine to the blue compound by the enzyme, fat, and oxygen and by the fat peroxides. Hydroquinone and catechol inhibit the oxidation of carotenoids by the enzyme, fat, and oxygen; phloroglucinol and resorcinol have little effect.

Correlation of these induced and secondary oxidation reactions with oxidation reactions observed in living cells leads to the conclusion that the former may play a role in the normal cellular combustion or metabolism of organic compounds. It is believed that the great multitude of diverse chemical substances may be consumed in an organic furnace fired by a few principal foods and regulated by a restricted number of specific enzymes.

THE QUANTUM EFFICIENCY OF PHOTOSYNTHESIS

ROBERT EMERSON AND CHARLTON M. LEWIS

It has been explained in earlier reports that the quantum yields measured by the method of Warburg and Negelein were subject to certain errors, and that if the method was modified to avoid these errors, lower yields were obtained. Certain characteristics of the quantum yield were discussed in last year's report, based on measurements in sodium light ($\lambda=589\text{m}\mu$). The importance of extending the work to other regions of the spectrum was emphasized. This was made possible by the completion of our monochromator in August 1940. Mr. Harold D. Babcock, of the Mount Wilson Observatory, generously provided us with a large grating ruled on an aluminized glass disk, which had sufficient brightness and dispersing power to meet our requirements. Other members of the Observatory staff were most helpful in the work of design and construction of parts. A small grant from the National Research Council made possible the purchase of optical and mechanical parts which enabled us to take full advantage of the capacity of the grating. It is believed that the resulting instrument has an enduring value for plant physiological work, and a description of it is being prepared for publication.

With a 1000-watt water-cooled incandescent lamp as a light source, it has been possible to measure photosynthetic efficiencies in the red and near infrared regions with bands only 50 Å wide. Wider bands were necessary toward the blue and violet, to compensate for the lower output of the lamp at shorter wave lengths. By using bands of 100 to 150 Å, it was possible to obtain measurable photosynthesis as far as 410 mμ.

The dependence of quantum yields on wave length was studied with *Chlorella pyrenoidosa*, and with a species of *Chroococcus*. A few runs were also made with the small aquatic flowering plant *Wolfiella lingulata*, which gave results in substantial agreement with those for *Chlorella*.

Our experience in culturing and handling the *Chroococcus* is limited to a few months, and may be capable of much improvement. Of special importance is the observation that this organism grows well in media to which no potassium salts have been added, but fails to grow if no sodium salts are present. This is the opposite of the behavior of most plants. For experiments on photosynthesis, the *Chroococcus* cells were suspended in carbonate-bicarbonate mixture prepared either with sodium

salts or with part sodium and part potassium salts. The mixture used for *Chlorella*, made entirely from potassium salts, is toxic to *Chroococcus*.

In some cases the photosynthesis measurements were followed by extraction of the pigments from the cells, separation into green and yellow fractions, and measurement of light absorption by the extracts. These extractions and absorption measurements were made by Mr. H. H. Strain, whose experience in handling plant pigments was of the greatest help to us.

The earlier technique of measuring light energy was followed, with minor modifications to adapt the optical system to the monochromator. Rates of photosynthesis were based on oxygen exchange measured manometrically in carbonate-bicarbonate mixture, at a temperature of 20° C.

The rate of respiration was measured before and after each light exposure, and in correcting the apparent photosynthesis for respiration the conventional assumption was made that the rate of respiration was the same during the light exposure as the observed rate before or after the light exposure. Minor changes in respiration in response to light, which failed to persist into the dark period when respiration was measured, constitute a potential source of error, the magnitude of which may vary with wave length. Experiments with the monochromator have shown that a narrow band of wave lengths in the neighborhood of 480 m μ has a strong effect on respiration. The rate may increase 50 to 100 per cent during 10 or 15 minutes light exposure. The accelerated rate of respiration seems to continue substantially unchanged for a sufficient length of time after the light is turned off so that the rate measured during the dark period is still a close approximation to the rate which prevailed during the light exposure. It is worthy of note that the wave lengths responsible for this

effect on respiration are in the region of strong absorption bands of the yellow pigments, suggesting a possible relation between these pigments and respiration.

The delay entailed by the frequent measurements of rate of respiration made it impossible to cover more than four or five wave lengths in a single experiment. Sometimes these were chosen to cover a wide range of the spectrum, and sometimes they were limited to a narrow region. The curves shown in this report are the composite result of many separate but overlapping experiments.

In general, measurements of light absorption were avoided by using suspensions of cells thick enough to absorb all the incident light. For measurements with thinner suspensions, the fraction of light transmitted was measured by placing a "photronic" photoelectric cell in the light path directly behind the cell suspension.

Figure 1 shows the dependence of quantum yields on wave length for *Chlorella* (solid curve) and for *Chroococcus* (broken curve). Both curves show a region of relative flatness in the red part of the spectrum from about 580 to 680 m μ , with a steep decline toward the infrared and a more gradual decline toward the green. In the case of *Chlorella*, the yield in the red region may be regarded as the quantum yield of chlorophyll activity, since the absorption of light in this region by the other pigments known to be present in *Chlorella* is certainly negligible as compared with the absorption by chlorophyll. Probably no great significance can yet be attached to minor fluctuations of the quantum yield in the red region, because of the possibility that they may be due to undetected effects of light on respiration. The steep decline toward the infrared seems too extreme for any such interpretation, and is interesting because it begins near the maximum of the red absorption band of chloro-

phyll. Possibly wave lengths greater than about 680 m μ provide quanta of insufficient energy to accomplish photosynthesis. If the absorbed quanta are too small to raise the chlorophyll to the energy level where it can emit fluorescence, then it is probable that the photochemical primary process cannot take place. The sharpness of the drop in quantum yield toward the infrared and the fact that it occurs close to the maximum of the fluorescence band are favorable to this interpretation.

sorbed by these pigments is lost for the process of photosynthesis. The rise again in the blue would be expected because the proportion of light absorbed by chlorophyll is believed to increase here.

Such an interpretation is supported by experiments with thin suspensions. At low light intensities, the photosynthetic activity of thin suspensions should parallel the absorption spectrum of the photochemically active pigment. Using the rate of photosynthesis per unit of incident light as a

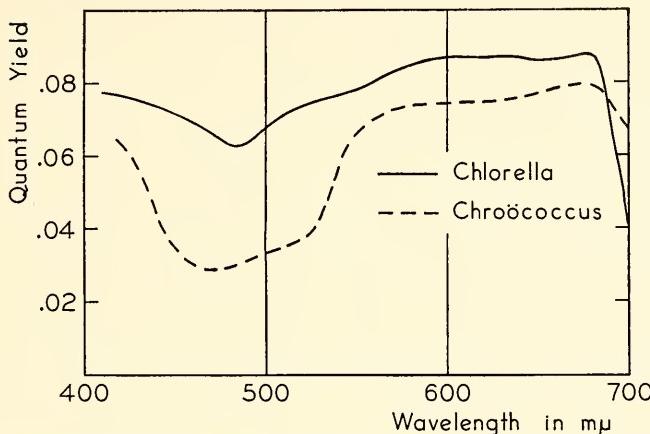


FIG. 1. Quantum yield of photosynthesis of *Chlorella* and *Chroococcus* as a function of wave length

Toward the blue from 680, on the other hand, the energy per quantum increases, and should always provide sufficient energy to raise chlorophyll to the energy level where it can emit fluorescence. A constant quantum yield for the light absorbed by chlorophyll is therefore to be expected. Lower yields can result, however, from absorption of part of the light by pigments photochemically inactive in photosynthesis.

The yield reaches a minimum near 480 m μ . This is a region where a large proportion of the light is absorbed by the carotenoid pigments, and a reduced yield could therefore mean that the light ab-

measure of photosynthetic activity, we have compared the dependence of activity on wave length with the light absorption, measured for the same suspensions with a photocell. In red, where chlorophyll alone is responsible for the absorption, the activity closely parallels the absorption. But as the region of light absorption by the carotenoids is entered, the activity begins to fall below the absorption, indicating that some of the absorbed light fails to be used in photosynthesis.

Comparison between *Chroococcus* and *Chlorella* also favors this interpretation. The minimum in quantum yield is lower for *Chroococcus*, and extends farther to

ward the red. Pigment extracts from the two species show that *Chroococcus* contains relatively more carotenoid pigments, and that the light absorption by these components extends farther toward the red than in the case of *Chlorella*. But a quantitative comparison between the figures for light absorption by the extracted pigments and the quantum yields raises some doubt that so simple an interpretation can be correct. The decline in yield begins in the yellow or yellow-green, where it seems hardly possible that the yellow pigments can absorb an appreciable fraction of the light. On the other hand, the proportion of light absorbed by carotenoids at 490 or 500 is so great that if they are photochemically inactive in photosynthesis the minimum in the quantum yield should be much lower than we have found it to be. And although the proportion of light absorbed by the chlorophyll increases somewhat in the blue, the measurements with extracts would not lead us to expect quantum yields so closely approaching the red maximum, because the carotenoids still absorb strongly in blue.

Some allowance must be made for differences between absorption spectra in intact cells and in pigment extracts, but at best it seems impossible to give a satisfactory interpretation of the quantum-yield curves in terms of the photochemical inactivity of the carotenoids. Possibly some of the

yellow pigments may contribute the energy they absorb to photosynthesis. It is also conceivable that the quantum yield for the light absorbed by chlorophyll is not constant. A complete interpretation of the results seems to require further evidence.

One of the interesting features of the *Chroococcus* is its blue pigment, phycocyanin, which absorbs strongly in the yellow and orange region, where the chlorophyll absorption is diminishing. The fact that the efficiency of *Chroococcus* photosynthesis remains high in this region is strong evidence that the light absorbed by the phycocyanin is available for photosynthesis. Convincing proof of this is furnished by experiments with thin suspensions, comparing again the photosynthetic activity with the light absorption. The curve for light absorption shows two maxima, one at 625 for phycocyanin, and the other at 675 for chlorophyll. The curve for photosynthetic activity closely parallels the absorption curve, and shows the same two maxima. The excellent agreement between these curves shows conclusively that the light absorbed by the two pigments is equally effective in carbon dioxide assimilation.

This project on the quantum yield of photosynthesis has now been terminated. The authors take pleasure in thanking the Carnegie Institution for the courtesies and privileges extended to them.

EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The program in experimental taxonomy follows two general lines, both dealing with plant relationships. The first of these concerns the relation between plants and their environments, including their fitness to and modification by environment. The second deals with the kinships or relation-

ships of plants to one another. Previous Year Book reports have outlined progress in studies on the environmental relationships of plants, especially as related to climate. The present report deals particularly with the relationships of plants to one another.

CRITERIA FOR RELATIONSHIP

Several groups of factors are indicators of relationship between plants. The nature of the ties and barriers that mark the degrees of relationship can therefore be determined in several different ways, as follows: (1) by morphological resemblances and differences; (2) by geographic-ecologic distribution; (3) by fertility tests of hybrids and the vigor of the second-generation offspring; and (4) by cytological evidence, as revealed by chromosome numbers and pairing between chromosomes in interspecific hybrids.

It was conceivable that the morphological, geographic-ecological, genetical, and cytological methods might yield very different results if each of them were applied exclusively in determining plant kinships. At the outset of the present investigations very little was known as to how the results from the four methods would correlate if all were applied to the same group of plants, for only scattered attempts in this direction had been made previously.

The morphological method is the one used in classic taxonomy. One of its shortcomings is that there is no way of telling which characters are the most important for classification. Usually, however, major morphological gaps involving many characters also represent major genetic discontinuities. Relationships based on morphology alone have therefore frequently coincided with those determined by other methods. But dependence on morphology alone proves inadequate in groups where selection has not yet eliminated the intermediate forms.

The geographic-ecologic method supplements the morphological one. Wild plants are intimately dependent on their natural environment and succumb if they are not suited to it. Their differences in fitness to specific environments are often reflected

in visible morphological characters. Conversely, morphological variations that are not correlated with any particular environment have seldom been found to be of major importance in other respects. What the differences mean in terms of kinship and classification cannot be determined by geographic-ecologic or by morphologic methods alone.

The fertility of F_1 offspring between parents of known morphological and ecological relationships and the vigor of their segregating F_2 populations have proved to be reliable indicators of genetic relationship in almost all groups of plants investigated. This has led to a definite conception of the affinities between members of a genus. It is axiomatic that plants which will cross and produce vigorous hybrids, and which are able to exchange their genes without detriment to the offspring, are closely related genetically. Plant groups are found that represent all stages of genetic affinity, as shown by a decreasing scale of fertility and vigor in their hybrids.

In applying the cytological method, one first determines the number of chromosomes characterizing each form within the group. A knowledge of chromosome numbers aids in dividing the genus into natural subdivisions and may call attention to species which might otherwise escape detection. The next step is the study of pairing of the chromosomes in F_1 hybrids. This unfolds still another picture of relationship, that of homology between chromosomes. Broadly, this picture coincides with that obtained from the fertility test, because cytologically very irregular hybrids are usually also very sterile. Some hybrids, however, that are regular cytologically may be just as sterile. Complex genic changes may therefore take place within the chromosomes of related species without appreciably affecting the homology or pairing of the chromosomes themselves.

All this may indicate that, from the evolutionary standpoint, the structure of the chromosomes is relatively stable. In general, therefore, the results obtained by the cytological method are less selective than those obtained by fertility tests.

A comparative investigation of the ties of relationship as revealed by these four methods is being carried out on the approximately seventy species of the subtribe Madiinae of the sunflower family that have been used in experiments. These compose eight natural groups (genera or subgenera), the members of each of which have been extensively intercrossed. These groups are *Euhemizonia*, *Deinandra*, and *Centromadia* of the genus *Hemizonia*, and the genera *Lagophylla*, *Layia*, *Madia*, *Holocarpha*, and *Calycadenia*. The analysis of the genus *Layia* is now so far advanced that the results obtained can be graphically presented as shown in figure 2.

RELATIONSHIPS IN THE GENUS LAYIA

Fourteen groups in *Layia* are now recognized as sufficiently distinct to be called species. These differ both as to the size of the area they occupy and as to the amount of their variability. This is illustrated by the variation in the size of the shaded areas around the circles representing the species in figure 2, except that the actual differences are much greater than could be indicated. Each of the fourteen species can be recognized morphologically, and a series of some fifteen to twenty morphological characters furnish them with good markers. The arrangement of the species in the figure, beginning with *chrysanthemooides* and ending with *heterotricha*, approximates their order of morphological resemblance.

Morphologic-geographic relations. The dotted radial lines indicate major morphological discontinuities, or breaks, within the genus. They divide it into six groups, two

of which contain single species. Clockwise around the figure from *chrysanthemooides* to *Jonesii*, the species are characterized by having scaly pappus, in contrast with all the remainder, which have bristly pappus. Were one inclined to divide *Layia* into subgenera on the basis of morphological evidence alone, he would no doubt separate it into two, running the division between *Jonesii* and *platyglossa* and stressing the pappus character as the outstanding one. The five species with scaly pappus are again divisible into subgroups on the basis of morphology. The first two, *chrysanthemooides* and *Fremontii*, differ from all other Layias in having a bract subtending each floret in the head and in lacking all glands.

The geographic-ecologic relations of the species with scaly pappus are very characteristic. *Layia chrysanthemooides* is found in the northern and central Coast Ranges of California, whereas *Fremontii* occupies the Sierran foothills. The next group of three are more southern, each with a limited distribution, so-called local endemics. They grow in very different habitats, *leucopappa* in the foothills at the head of the San Joaquin Valley, *Munzii* to the westward in flats of heavy mud in the inner Coast Range, and *Jonesii* still farther west near the coast. These three do not come into physical contact with one another, nor with any other species with scaly pappus.

The species with bristly pappus cannot easily be divided into groups by means of single outstanding characters, nor even by blocks of characters, except in the case of the group including *gaillioides*, *hieracioides*, and *paniculata*. Furthermore, the species themselves can scarcely be separated by single key characters, for the most conspicuous characters often vary even within the species. For example, ray color is variable in *platyglossa*, *glandulosa*, *pen-*

tachaeta, and *gailliardiooides*, and anther color in *platyglossa*, *paniculata*, and *heterotricha*. Pappus varies both as to the num-

of these and other characters. Many characters are quantitative rather than qualitative, and are accordingly best expressed

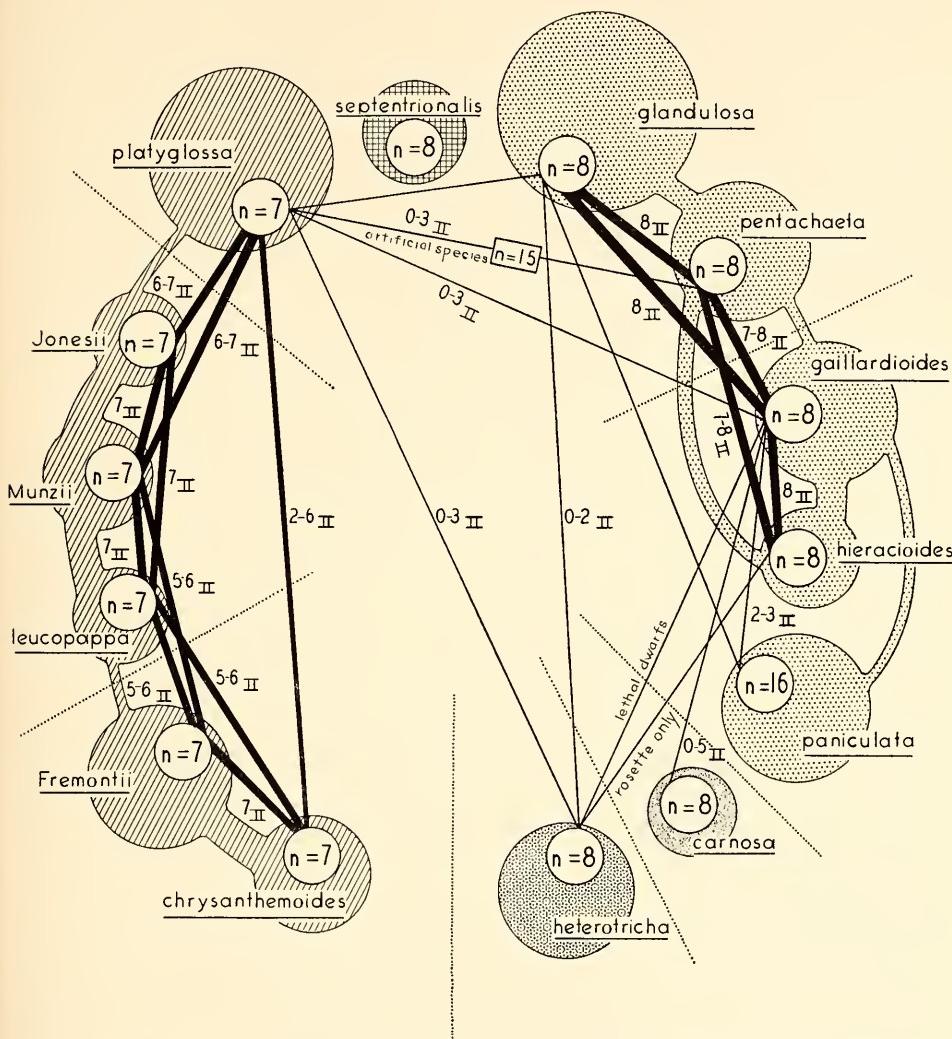


FIG. 2. Relationships in the genus *Layia*. The circles represent species, with chromosome numbers indicated; shaded connections show degree of genetic affinity, and width of solid black lines represents degree of chromosome pairing in interspecific hybrids. The dotted lines indicate major morphological breaks in the genus. (See text.)

ber of units and the quality of its pubescence in both *platyglossa* and *glandulosa*. Most of the species, therefore, contain forms marked by different combinations

as modes. The remotest species in the series from *platyglossa* to *paniculata* are morphologically extremely different, but the intervening ones represent transitional

steps. Once their complex relationships have been worked out, however, the species can easily be separated by the combinations of characters marking the forms of which they are composed.

The four species in figure 2 delimited by *platyglossa* and *pentachaeta* are morphologically the most intricately related, but in their distribution they follow a simple pattern. They cover a large territory but overlap very little. *Layia platyglossa* is common from northern Baja California north through the Coast Ranges and along the western side of the San Joaquin Valley to the north of San Francisco Bay. *Layia glandulosa* is the only species on the deserts, occurring in sandy soils from Washington and Idaho to northern Baja California and New Mexico; toward the southern part of its range it approaches the coast. *Layia pentachaeta* occurs in somewhat heavier soils in the Sierran foothills, and around the head of the San Joaquin Valley to the southern part of the inner South Coast Range. *Layia septentrionalis* is a local endemic in the inner North Coast Range in an area left unoccupied by the other three.

Layia gaillardiooides, *hieracioides*, and *paniculata* form a morphologically closely knit group that is distinguishable from the others by conspicuously black-dotted stems, a characteristic fragrance, urn-shaped involucres, and other characters. This group is found in woodland or chaparral environments, in contrast with the other Layias, which are almost exclusively confined to grassy open places. The ranges of the three species adjoin and slightly overlap, *gaillardiooides* inhabiting the northern and central Coast Ranges, *hieracioides* the hills around San Francisco Bay, and *paniculata* the southern Coast Ranges.

Layia carnosa and *heterotricha* are morphologically quite isolated from each other and from all other Layias. The delicate

carnosa is known from only a few widely separated localities in coastal sand dunes in California, a habitat eschewed by all other species in the genus. The very robust, hollow-stemmed, strong-odored *heterotricha* is found sporadically in heavy adobe over a considerable area in the southern Coast Ranges.

The morphological and ecological pattern produced by the species of *Layia* is typical of many plant groups, although admittedly a little more complex than that found in most genera. Consequently, it is of interest to consider how the concept of relationship based on these criteria conforms with those based on genetical and cytological data.

Genetical relations. In figure 2 the species are represented by circles within shaded areas. The widths of the shaded connections indicate the relative ease or difficulty with which genes can be transmitted back and forth from one species to another, as determined by the fertility of their first-generation hybrids and by the relative vigor of the second generation. The latter information indicates what chance of survival a hybrid population might have under natural conditions. The diagram is based on extensive crossing data, each successful hybridization being represented by a line connecting the symbols of the parental species. The many unsuccessful attempts at hybridization are not shown, in order to simplify an otherwise complex picture. The intraspecific hybrids, characterized by fertile F_1 and vigorous F_2 populations, have likewise been omitted.

It is immediately obvious from the genetic data that the major morphological discontinuities separating *Fremontii* from *leucopappa*, *Jonesii* from *platyglossa*, and *pentachaeta* from *gaillardiooides* are reflections of major genetic barriers. Hybrids between these groups are only 0.5 to 2 per cent fertile, and their offspring are usually

weak. Likewise, the isolated morphological positions of *carnosa* and *heterotricha* are borne out by the crossing data. It has been impossible for these species to exchange genes with any other. The hybrids of *heterotricha* with *gaillardioides* and *hieracioides* failed to survive beyond the rosette stage.

On the other hand, the morphological criteria failed to indicate the genetic barriers in the complex group composed of *platyglossa*, *septentrionalis*, *glandulosa*, and *pentachaeta*. They did not show that *platyglossa*, with bristly pappus, is genetically much more closely related to the species with scaly pappus than to those with its own kind of pappus, nor that *septentrionalis* is completely isolated genetically. The latter is the only species of *Layia* which, in spite of many attempts, has been unable to hybridize with any other.

The genetic evidence has brought to light the close relationship within certain groups of species (species complexes or cenospecies). The hybrids between *Fremonii* and *chrysanthemoides* were approximately 30 per cent, and those between *Munzii*, *leucopappa*, and *Jonesii* approximately 25 per cent fertile—high percentages for interspecific hybrids. These fertilities are so high and the percentage of weak second-generation offspring so low that, from the genetic point of view, one is tempted to consider these to be only incipient species. Probably, however, even relatively weak genetic barriers would be sufficient to maintain a differential selection under natural competition. Furthermore, these species happen to be both morphologically and ecologically very well separated, and the rarity of the latter three makes physical contact impossible between them under present-day conditions.

The hybrids between *pentachaeta* and *glandulosa* were only 8 to 10 per cent fertile, with some weakness in the second

generation. *Layia gaillardioides* produced very fertile hybrids with *hieracioides*, but in this case the elimination took place in the second generation, of which approximately 71 per cent were weak, retarded, or subnormal. The third generation of this hybrid was even less adapted to survive in nature, for 92 per cent of approximately 1000 plants, representing 9 cultures, were subnormal.

The fertilities observed in one hybrid combination are usually a good measure of what can be expected of other hybrids between members of the same species complex. One exception to this rule is to be noted from the diagram. The hybrids of *gaillardioides* with *glandulosa* and *pentachaeta* were 1.8 and 1.6 per cent fertile respectively, whereas the hybrid between *hieracioides* and *pentachaeta* was 7 per cent fertile and its second generation was less weakened.

Chromosome numbers. The investigation on chromosome numbers revealed that *Layia* is divided cytologically into two groups, the species with 7 pairs and those with 8 or 16 pairs. The number characteristic for each species is indicated within each circle in figure 2. In most cases this number is based on counts from many populations, and therefore the constancy of the chromosome number within the species has been safely established. The cytological classification separating the species with 7 from those with 8 pairs of chromosomes coincides with one of the most distinct genetic barriers in the genus and confirms the genetic position of *Layia platyglossa*, but it bisects the morphological group of which *platyglossa* and *pentachaeta* are the extremes. In fact, the cytological division shattered an artificially long-maintained species based on pappus characters, *L. elegans*. The 7-chromosome element of this “species” was found to be a simple genetic variant of *platyglossa*, and

its two 8-chromosome fragments were found to constitute respectively a yellow-flowered subspecies of *glandulosa* and the new species *septentrionalis*, genetically the most distinct in the entire genus. The chromosome counts also called attention to the presence of a new tetraploid species, *paniculata*, discussed in Year Book No. 39 (1939-1940), page 162.

The chromosomes of most *Layia* species are morphologically alike, but 4 of the chromosome pairs of *L. heterotricha* are only about half the size of those of the other species, adding to the picture of isolation for this species as already gained from its morphological and genetical positions.

Chromosome homology. A very important evolutionary relationship is thought to be expressed by the degree of pairing between specifically different chromosomes in interspecific hybrids. In figure 2 the relative width of the lines connecting the species indicates the degree of pairing in the hybrids. The heaviest lines represent complete or almost complete pairing; thin lines indicate very little pairing. The number of pairs observed is indicated by the figures beside these lines. It will be seen that all the 7-chromosome species appear to have homologous or almost homologous complements of chromosomes irrespective of the two very distinct genetic barriers separating them, namely, those between *Fremontii* and *leucopappa* and between *Jonesii* and *platyglossa*. Pairing is somewhat reduced in the sterile hybrids between the two remotest species, *platyglossa* and *chrysanthemoides*. The chromosomes of *platyglossa* pair with those of *Jonesii* although those of the two species differ somewhat in size. Three of the chromosome pairs in this hybrid consist of unequal partners. Apart from this observation, none of the phenomena commonly ascribed to translocation or segmental interchange

between nonhomologous chromosomes or to inversions of parts of chromosomes have been observed in any of the *Layia* hybrids.

Layia glandulosa, *pentachaeta*, *gailliardoides*, and *hieracioides*, of the 8-chromosome species, form a similar closely knit group with homologous chromosomes, as evidenced by almost perfect pairing in their hybrids. These species have not evolved through the simple addition of one chromosome to those of the 7-chromosome group, for there is almost no pairing of chromosomes in the rare hybrids between 7- and 8-chromosome species. The occasional pairs are very long and show loose connections. This behavior suggests that irrespective of morphological resemblance between *Layia platyglossa* and the 8-chromosome species, they must have been separated for a long time during their evolutionary history.

The tetraploid *Layia paniculata* appears to be genetically connected with this group, because 37 F₂ plants were raised from a cross of *gailliardoides* × *paniculata*. But these were all offspring of a tetraploid hybrid produced by the fertilization of a rare diploid *gailliardoides* ovule, containing 16 chromosomes, by a normal *paniculata* pollen grain, also with 16 chromosomes. The chromosomes of *paniculata* are not homologous with those of the *gailardioides* group, however, as the morphological resemblance between *paniculata* and *hieracioides* would suggest, for no more than 2 to 3 pairs were formed in their triploid hybrids. This is also evidence against the idea that *paniculata* arose through a simple doubling of the chromosomes of *hieracioides*, for in such a case one should expect the 16 *paniculata* chromosomes to pair among themselves in this hybrid, resulting in at least 8 pairs. Actually, the pairing behavior suggests that *paniculata* had an entirely independent

origin, probably from ancestors at least one of which is now extinct.

There is very little homology between the chromosomes of *Layia carnosa* or *heterotricha* and those of other 8-chromosome species, for very few and imperfect pairs were found in their hybrids. The *heterotricha* chromosomes proved nonhomologous with those of both the *platyglossa* and the *glandulosa* group. Peculiarly, it is often the short chromosomes of *heterotricha* which are able to pair with the longer chromosomes of the other species, for heteromorphic pairs, consisting of one long and one very short partner, were repeatedly found.

Cytologically, then, *Layia* includes two major blocks of species, one with 7, the other with 8 pairs of chromosomes. Within each group the chromosomes are homologous, but between the two groups they are nonhomologous. *Layia heterotricha* represents a third cytologically distinct unit; *carnosa* and *paniculata*, the latter polyploid, may represent remnants of formerly more complex groups. The position of *septentrionalis* cannot be determined, because it has been impossible to produce any hybrids with this species.

The mosaic of relationships. Bringing together the morphologic, ecologic, genetic, and cytologic evidences and integrating them with the study of populations discussed in Year Book No. 39 (1939-1940), pages 159-160, we can visualize the relationships in *Layia* as follows:

The genus is composed of groups of populations fitting various environments. These groups are arranged into species, which are separated by genetic barriers of various distinctness. The species can be recognized by morphological characters, which serve as markers for the boundaries determined by genetic methods, but are not themselves of primary importance. Some species have narrow limits of dis-

tribution and little variation, being fitted to only one ecologic-geographic niche; others are widely distributed, with several major ecologic races and much variation.

Because of differences in the distinctness of the genetic barriers, some species arrange themselves in complexes of higher order (for example, *chrysanthemoides-Fremontii* and *leucopappa-Munzii-Jonesii*), the members of which occupy different ecological niches. Other species lack genetically close relatives and form monotypic groups, usually showing comparatively little variation.

The genetic complexes of species may combine into cytological units of still higher order with homologous chromosomes, that is, chromosomes that pair when brought together in a hybrid. These larger cytological units are probably related to the broader evolutionary lines in the genus. The genetic and cytologic pictures of relationship are often roughly similar, but not at all identical.

Evidence of relationship should, therefore, not be sought along either morphological, ecological, genetical, or cytological lines alone, but through the employment of all four criteria considered together, because each contributes to a more complete understanding of it. Such a review provides a depth of perspective to the picture of natural relationships.

The genus *Layia* has proved to be a most suitable subject for such a study. Its units are in all stages of evolutionary differentiation, and it is equally well suited for extensive investigation by all four methods.

Evolutionary prospects of Layia. The cytogenetic gap between the 7- and 8-chromosome species of *Layia* can be spanned, although such bridges have not yet arisen in the wild. Diploid sex cells containing all 15 chromosomes of the combined *platyglossa* and *glandulosa-gaillardiooides* com-

plexes are fairly commonly produced in hybrids between their members. Such diploid sex cells may give rise to triploid and tetraploid offspring and finally result in true-breeding, new amphidiploid species having the sum total of the parental chromosomes with all their genes.

A constant population with 15 pairs of chromosomes is arising in this manner from the hybrid *pentachaeta* \times *platyglossa* (see fig. 2). This artificial new species is intermediate in appearance between the two morphologically related parents, but cytogenetically it is very distinct. The parental species meet at one known place in the wild, in the inner South Coast Range, and from seed collected there we obtained two natural hybrids. These duplicated in appearance and behavior the much larger hybrid population previously produced in the experiment garden. This hybrid was extremely sterile, but it was possible to obtain 11 triploid and 3 tetraploid offspring from 10 F_1 individuals permitted to flower together during an entire season in a plot isolated from other Layias. The fairly constant tetraploid, 15-paired population was produced from these in the third hybrid generation.

Some 12,000 florets from about 400 heads yielded only the 3 amphidiploids in the garden experiment. In the wild the plants are smaller and fewer heads are produced. For that reason it is estimated that, once the very infrequent meeting of the parental species occurs, it would require a colony of about 26 F_1 plants to yield 2 amphidiploids if there were no greater loss of seed than under greenhouse germination. The chance that that many hybrids will occur at one time in one place is exceedingly remote.

Assuming, however, that the necessary number of amphidiploid plants have been produced, a species in the making faces other serious hazards before it can estab-

lish itself. Its success will depend on its ability to occupy an available environmental niche as well as or better than the species already there, and to establish offspring before it is exterminated.

Natural evolution is therefore a slow process, and species are able to maintain themselves relatively unchanged for ages. New steps in evolution may be expected when environments have changed, furnishing new niches for new plants to occupy. In the present experiments, evolutionary processes are accelerated to a high degree, and one might venture to suggest on the basis of present evidence that 15-chromosome Layias may in the future replace some of the present-day species.

A POSSIBLE NEW SPECIES OF LAYIA

A small population of a hitherto unknown plant was discovered a year ago by Mrs. Roxana S. Ferris and Dr. I. L. Wiggins, of Stanford University, in a remote locality in the inner South Coast Range of California. Technically this plant would appear to belong to the tribe Helenieae, as its receptacle is bractless, its involucre has only one row of bracts, and its heads have no ray florets. Doubtless, however, it is not referable to any known genus in that tribe. Considering its pappus, florets, bracts, habit, herbage, and vesture, it seemed to belong very close to the genus *Layia* even though the absence of outer involucre and ray florets deprived it of the essential key characters for admission into the subtribe Madiinae. It was supposed to be either a new genus of uncertain affinities or an anomalous member of *Layia* or possibly *Madia* of the Madiinae. It was hoped that hybridization tests would help to place it.

Dr. Wiggins kindly led us back to the only known and very limited colony of it this year, and from material collected a

number of plants were cultivated in the greenhouses. It has 8 pairs of chromosomes, and, in crossing, its pollen produced a considerable amount of apparently good seed on *Layia glandulosa* and *gaillardioides*, also both with 8 pairs of chromosomes. The first experimental evidence, therefore, suggests that it may be a new species of *Layia* rather than a new genus of another tribe. This would add a species with scaly pappus to the 8-chromosome Layias, which would counterbalance the situation of *platyglossa* among the 7-chromosome Layias.

SYNTHESIS OF A PRE-EXISTING SPECIES OF *MADIA*

It was mentioned in Year Book No. 36 (1936-1937), page 211, that a new *Madia* species with 24 pairs of chromosomes, the highest number found in the Madiinae, had been discovered in northeastern California. Since that time this species has been re-collected. In most characters it resembles *Madia gracilis*, with 16 pairs of chromosomes, but in other respects it is like *M. citriodora*, with 8 pairs. Both of these are natives in the region from which the new species came. This species has now been artificially produced by crossing.

The self-fertile *Madia citriodora* and *M. gracilis* were cultivated together in an isolated plot for possible hybridization. One hybrid appeared among 400 selfed offspring of *gracilis*. This plant was recognized by its morphological similarity to the new species, and its hybrid nature was proved by the number and behavior of its chromosomes. The chromosomes of this hybrid were found to remain almost completely unpaired, and a certain percentage of sex cells were formed which contained all the 24 chromosomes of both parents. Apparently these sex cells were almost the only ones to produce viable offspring, for 46 of the 49 F₂ plants ob-

tained were found to have 48, or nearly 48, somatic chromosomes. Only 2 plants had 32 chromosomes, and 1 had approximately 40. A high percentage of plants with 24 pairs of chromosomes should be expected among the 48-chromosome survivors, all of which resemble the new 48-chromosome wild species, *Madia citrigracilis*. Variation in fertility among these plants, however, indicates that they are not of identical genetic constitution, so probably some further elimination is necessary to produce in a subsequent generation an entire population that replicates the natural new species.

OTHER INVESTIGATIONS

The cytological analysis of *Madia* hybrids analogous to that described for *Layia* is in progress. It can already be seen that most *Madia* species are cytologically and genetically more isolated than those of *Layia*. A number of additional Madiinae cultures were grown this year to supply information necessary for the completion of the investigations on this subtribe. Also, the geographic distribution of genes determining pappus characters in *Layia platyglossa* and flower color in *Madia elegans* is being mapped to help solve specific evolutionary problems.

The selection experiment entered its third year of observation at the transplant stations. From preliminary examinations this summer it appears that most of the elimination took place during the first two years of the experiment. A number of plants, selected on the basis of their reactions during the first two years, have been selfed to produce third-generation hybrids which are expected to represent ecotypes in the making.

Plant materials for an intensive study of climatic races of *Achillea* and *Potentilla glandulosa* are being assembled. Races from altitudinal intervals of 1000 feet along

the station transect are to be utilized in this program as a basis for a future study of the physiology of climatic races. Thorough and more extensive tests of reactions

at the transplant stations will furnish the necessary background for more intensive investigations to be made under laboratory conditions.

DESERT INVESTIGATIONS

FORREST SHREVE

Two projects for investigation of major subdivisions of the North American Desert are now being carried on. The results of the older project, on the Sonoran Desert, are now in an advanced state of preparation for publication. Work on the Chihuahuan Desert area is still in an early stage of progress. In each of these investigations the study of the natural plant communities and their environmental relations has been carried on in cooperation with other workers who are endeavoring to secure a complete enumeration of the species of plants indigenous to the areas. Dr. Ira L. Wiggins, of Stanford University, has been devoting an important part of his time for several years to the difficult task of completing the record of the plants of the Sonoran Desert, so many extensive parts of which had not been previously explored by plant collectors. Dr. Ivan M. Johnston, of the Arnold Arboretum of Harvard University, has contributed his long experience with the desert plants of North and South America to the preparation of a flora of the Chihuahuan Desert.

The close sequence of the periods of field work on the lowland and highland deserts of northern Mexico and the southwestern United States has been of great value. Not only have the individual features of each area been determined, but their many contrasts have been made more vivid. These have their basis chiefly in the conditions which accompany differences in altitude. The Chihuahuan Desert includes the highest arid areas in North America,

lying 7000 feet above the lowest coastal plains of the Sonoran Desert. The orographic features which cause aridity at high elevations do not, however, bring about a climate identical with that of the lowlands. Throughout the entire vertical range of desert there are a few plants of continuous occurrence, many of similar life form, and a few communities with closely similar features. The floristic composition of the lowland and highland deserts differs widely.

CHIHUAHUA DESERT

During the summer of 1940 field work on vegetation in the Chihuahuan Desert was carried on by Dr. Shreve, accompanied by Dr. E. R. Tinkham, of the University of Arizona. Attention was mainly devoted to the southeastern edge of the area in Nuevo León and San Luis Potosí, lying between areas previously visited and the mountains which form the eastern edge of the Mexican plateau.

In Nuevo León the Sierra Madre Oriental forms a continuous ridge, rising in Cerro Potosí to 12,300 feet and in Peña Nevada to 12,020 feet. Fifty miles west of Peña Nevada, in the northern end of San Luis Potosí, is the Valle del Salado, one of the most arid parts of the Chihuahuan Desert. The dryness of this valley is attributable to its location in the "rain shadow" of Peña Nevada, and it was anticipated that even more arid conditions would be found near the western base of this range. It was found, on the con-

trary, that the heavy rainstorms which visit the mountains during the summer months are carried far enough inland by the prevailing winds to support a relatively luxuriant type of desert vegetation along the eastern edge of the desert opposite the highest peaks and ridges. West of the low gaps in the Sierra Madre the desert is more arid and many of its characteristic plants range up to the summit of the mountains and descend for short distances into the drainage of the Gulf of Mexico. The desert side of the Sierra Madre Oriental has only a few poorly developed areas of grassland, contrasting sharply with the broad belts of it along the eastern base of the Sierra Madre Occidental on the other side of the plateau desert. This contrast is due in large part to the prevailing granite soils in the latter case and the thin limestone soils in the former.

A brief examination was made of the eastern slopes of the Sierra Madre Oriental at two localities, in Nuevo León and Tamaulipas, and of the arid plains of Tamaulipas. This confirmed the decision, based on observations farther north, that the eastern mountain slopes and the lowlands of Nuevo León and Tamaulipas are not to be regarded as a part of the Chihuahuan Desert. Although the lowlands of these states are arid, their vegetation differs in physiognomy and structure from that of the plateau desert, and the floristic composition is very unlike in the two.

Returning to the plateau, a trip was made through the foothills and lower slopes of a chain of mountains which nearly bisects the Chihuahuan Desert in southern Coahuila. These ranges lie in an east-and-west position and extend from the Sierra Madre Oriental nearly to the outlying foothills of the Sierra Madre Occidental. In the chain are several high ridges with mesophytic vegetation, including the Sierra de Parras and the Sierra Jimulco.

There are at least three low gaps, with extremely xeric vegetation, which connect the northern and southern expanses of desert. Through one of these gaps runs the Rio Aguanaval, which drains part of the desert of Durango and all that of Zacatecas into the enclosed Laguna Viesca. This central part of the Chihuahuan Desert has been little investigated from any angle and is the most important part yet to be covered by detailed work. A thorough collection of its plants is an important desideratum for the project.

A collection of 550 herbarium specimens was made by Drs. Shreve and Tinkham over the routes which they covered, and was turned over to Dr. Johnston for study. Dr. Tinkham is preparing a report on a collection of grasshoppers and crickets made in Mexico and Texas. The distribution of these insects is of botanical interest because it indicates faunal areas which coincide closely with floristic areas.

Further work on the flora of the Chihuahuan Desert was carried out during the past summer by Dr. I. M. Johnston, accompanied by Dr. C. H. Muller, of the Division of Plant Exploration and Introduction of the U. S. Department of Agriculture. Dr. Johnston and Dr. Muller devoted two months to exploration and collecting in northwestern Coahuila, in a region lying south of the Big Bend area of west Texas. Low mountain ranges here alternate with desert basins, some of which are undrained and several of which are highly alkaline. A very thorough examination was made of the Valle de Guaje and the basins around Salada Grande and Lago de Jaco, as well as of the desert slopes of Sierra de Pinos, Sierra La Encantada, and Sierra Las Cruces. Notes taken by Dr. Muller on the distribution of desert, grassland, and xeric oak woodland are a valuable contribution to the

study of the vegetation and the exact delimitation of the desert area.

Northwestern Coahuila was selected by Dr. Johnston for the season's work because of the lack of previous botanical exploration in the area and because of indications of its importance in the floristic history of the entire Chihuahuan Desert. A collection of over 1500 numbers was secured, including many novelties and numerous extensions of range. The latter group is particularly rich in plants known previously from the mountains around Monterrey.

From southern New Mexico to northern San Luis Potosí are scattered scores of gypsum deposits and areas of soil rich in gypsum. Dr. Johnston has given particular attention to the distinctive plant life of these deposits and has published (see bibliography) an annotated list of 38 species and varieties which appear to be confined to a gypsum-bearing substratum.

SONORAN DESERT

The main program of exploration in the Sonoran Desert was completed three years ago. During the late winter and early spring of 1941, however, there were such exceptionally heavy rains throughout the northern and western part of the area that several localities were regarded as worthy of further study. At that season particular interest attaches to the short-lived herbs, which appear in numbers proportional to the amount and duration of the late win-

ter rains. The distribution of these plants and their habitat occurrence and social organization are controlled by conditions almost wholly distinct from those governing the perennial plants. They are an outgrowth of the biseasonal rainfall of the central Sonoran Desert, which has recently been elaborated by Turnage and Mallory (see bibliography). As a part of the publication on the vegetation of the Sonoran Desert now in preparation, special treatment will be given the two distinct groups of winter and summer herbs. Their distribution in relation to rainfall periodicity is clear. The relation of their distribution to that of their congeners in neighboring regions, and their varying degrees of adaptation to desert conditions, bid fair to reveal some interesting facts in desert history. The desirability of taking advantage of the exceptional spring of 1941 was indicated by finding numerous species of herbaceous plants well beyond their previously known ranges, and finding species in great abundance in localities where they are usually infrequent.

Dr. Wiggins took advantage of the spring conditions to visit the desert slopes of the Sierra San Pedro Martir, in Baja California, and the almost rainless San Felipe Desert, on the coast of the Gulf of California in the lee of these mountains. The results of his expedition were very gratifying both as to the collections made and as to the notes secured on the vegetation of this poorly accessible region.

ECOLOGY

ADAPTATION AND ORIGIN

F. E. CLEMENTS, F. L. LONG, AND E. V. MARTIN

Comparative studies of evaporation and transpiration in relation to adaptation. Further investigations into the relation between the size of blotting-paper evapo-

rimeters and the rate of evaporation have been conducted the past year. Blotting papers of four sizes were employed: each was 10.2 cm. long, and the widths were 1.0, 3.8, 10.2, and 20.4 cm. By arranging these parallel to or at right angles to a constant-velocity wind, with other environ-

mental factors constant, it was found that the rate of evaporation per unit area varied inversely with the 0.3 power of the dimension parallel to the direction of the wind, and with the 0.2 power of the dimension at right angles to the wind. For square areas, this reduces to the 0.5 power of one side, which is the value that Leighly found to fit data taken by Banerji and Wadia with square evaporimeter pans. For surfaces in which the two dimensions are in a constant ratio, this law is equivalent to inverse proportionality to the 0.25 power of the area of the surface. Edith Shreve reported last year from the Desert Laboratory that the rate of evaporation per unit area from pieces of porous porcelain varied inversely as the 0.3 power of the area.

The influence of size of evaporating surface on the relation between rate of evaporation and temperature depression below air is very marked. In a wind of 250 cm./sec., the evaporation from a piece of blotting paper 10.2×20.4 cm. was only about half that from a strip 1.0×10.2 cm., whereas the temperature depressions differed very little. Conversely, if the evaporation rates were equal, the temperature depressions were in a ratio of about two to one. This same sort of phenomenon exists in overheating of bodies by radiation. With a radiation intensity of 1.0 cal./cm.²/min., a blackened copper strip 25 mm. square was heated above air temperature nearly three times as much as one 1×25 mm. In a quiet atmosphere, the temperature elevations were 24° and 9° C. respectively. A cylinder 1 mm. in diameter and 25 mm. long was heated only 6° C. under these same conditions. The difference between the cylinder and the 1-mm. strip is due to the fact that the former has a greater surface for conduction of heat to the surrounding air, but an equal surface exposed to the radiation. This illustrates a form of protection against

overheating entirely independent of the cooling effect of transpiration. This form is possessed in some degree by certain microphyllous species of the desert and by conifers.

An attempt to evaluate the insulating effect of hairs on a leaf was made by measuring the temperature depression of single detached leaves of *Salvia argentea*. For a given rate of transpiration per unit area, the temperature depression of the leaves was found to be approximately 1.6 times as great as that of a piece of blotting paper of about the same size and shape. This result was obtained with no wind, and is probably due to the insulating effect of the thick coating of hairs on the leaves. The much less hairy leaves of *Helianthus annuus* and *Ambrosia trifida* were intermediate between these two values. The fact that the temperature depressions of the latter two species are greater than that of blotting paper is probably due to the insulating effect of the epidermis of the leaves.

Measurements of the transpiration rate of single attached leaves of *Helianthus annuus* in a controlled environment in darkness showed that with no wind, at an air temperature of 27° C., the rate was only about half the rate of evaporation from a piece of blotting paper of the same size and shape, whereas at an air temperature of 49° C. and relative humidity above 25 per cent the rates are practically indistinguishable. Response of transpiration rate to wind increased markedly with air temperature, indicating that the cuticular component of transpiration was a function of the leaf temperature.

Further evidence of the relation between stomatal and cuticular components of transpiration was obtained by comparing transpiration rates of *Helianthus annuus* during the morning hours with those twelve hours later, all values being obtained

in darkness with environmental factors constant. At an air temperature of 27° C., the night rates averaged 65 per cent of the daytime values; at 38° C., 69 per cent; and at 49° C., 91 per cent. During the daytime runs the stomata remained wide open, whereas at night they were nearly closed, the air temperature having no apparent effect on the degree of opening. These data indicate that the cuticular component is of considerable importance at the higher temperatures.

Some studies of the effect of radiation on transpiration were made by using a 1500-watt Mazda lamp enclosed in a housing to provide ventilation and to insulate the lamp from the control room. A large part of the heat waves from the lamp were filtered out by passing the radiation through a glass cell 12 inches square containing a layer of water 1 cm. thick. For these experiments only single attached leaves of *Helianthus annuus* were employed. Under otherwise constant conditions, the relation between radiation intensity and transpiration rate was found to be linear within the range of intensities from 0 to 1.6 cal./cm.²/min.

With an intensity of incident radiation of 1.5 cal./cm.²/min., it was found that with a transpiration rate below about 1.6 g./dm.²/hr. the temperature of the leaf was above that of the surrounding air, whereas with rates above this value, the leaf was below air temperature. The balance point of 1.6 g./dm.²/hr. indicates that the leaf was absorbing only about 21 per cent of the incident energy. Measurements by a thermopile and spectrophotometer indicated that about 45 per cent of the incident radiation was transmitted and about 25 per cent was reflected, giving an absorption of 30 per cent, which is in rough agreement with the value obtained by leaf-temperature measurement.

The cooling effect of transpiration in

Helianthus annuus is very marked in the range of air temperatures from 35° to 49° C. with low relative humidity. For example, with a single attached leaf at an air temperature of 49° C. and relative humidity of 23 per cent, with radiation intensity of 1.5 cal./cm.²/min. and no wind, the temperature of the leaf was 12.5° C. below air temperature. In this case the average transpiration rate was nearly 4 g./dm.²/hr.

Further studies of comparative transpiration rates by the short-period weighing method for cut shoots and leaves were made on the plants in the adaptation garden at Santa Barbara. In the nutrient-water series, the small plants in the NW-0 group usually had higher rates of transpiration than the much larger ones in the NW-2 group, with those in NW-1 intermediate both in size and in rate. In the competition series, however, the very small plants in the plots with 128 and 256 individuals per square meter had rates lower than the large plants in the plots with 4 and 16 per square meter. Results from studies with blotting-paper evaporimeters would lead one to expect those plants with the smaller leaves to have the highest rates of transpiration. Consequently the results from these two series of treatments are in apparent contradiction to each other.

The explanation probably lies in the relation of the plants to the available moisture in the soil. In the nutrient-water series there was relatively little lack of soil moisture, even in the NW-0 group, with the result that none of the plants in this series suffered for lack of water during their growing season. Consequently, the plants with the smaller leaves show the higher rates of transpiration per unit area of the leaves. In the competition series, however, the plants in the plots with 128 and 256 per square meter must surely have suffered from lack of available water during the

growing season, and as a result developed a resistance to water loss which is not apparent in the groups of 4 and 16 per square meter, where soil moisture was abundant. This resistance to water loss is sufficient to overcome the tendency of the smaller leaves to have the higher rates.

In the lath-house series the plants in the shade have higher rates of transpiration in a given environment than those in the NW-2 group. In contrast with these results, the rate of transpiration of the shade shoots of the in-and-out plants was less than that of the sun shoots of the same

grown under four degrees of competition, namely 4, 16, 64, and either 128 or 256 individuals per square meter, the choice between the latter two densities depending on the size of the plants. All species responded in the same manner to this treatment, the only difference being in the degree of modification. Measurements were taken of the plants in the central part of the area, where competition was greatest. The individuals around the edges of the more densely planted quadrats were larger than those in the center. The usual response to the greater degrees of competi-

Dimensions	Plants per square meter			
	4	16	64	256
Plant height (cm.)	43	41	49	38
Stem diameter (cm.)	0.63	0.52	0.42	0.32
Number of stems per plant	10	5	4	2
Leaf length (cm.)	6.0	4.7	4.9	3.4
Leaf width (cm.)	3.3	2.4	2.4	1.5
Number of flowers per plant	33	13	7	3
Diameter of flowers (cm.)	2.6	2.2	1.6	1.3
Dry weight of shoots (g.)	21.6	8.4	5.2	0.95
Dry weight of roots (g.)	3.10	1.15	0.75	0.10

plant. Probably the explanation of this contradiction is the same as the one given above. In the lath houses the plants are grown with plenty of soil moisture available to each plant, whereas in the in-and-out group the sun parts of the plant may reduce the supply to the shade parts, causing the latter to develop a resistance to water loss which shows up as a reduced rate of transpiration. Many sun and shade individuals of the same species and single individuals of the in-and-out installation were later available at the Alpine Laboratory for use in checking both results and hypothesis.

Results in competition cultures. In addition to the usual installations in the adaptation garden at Santa Barbara the past year, seven species of plants were

tion was to produce fewer and smaller leaves, stems, and flowers; in some cases the production of flowers was delayed considerably. The dry weight of material produced declined with increasing competition; the height of the plants for four species was greatest in the 64 per square meter plot and for two others in the 16 per square meter quadrat. The response of *Chrysanthemum coronarium* was as nearly typical as any, and certain measurements are given in the accompanying table.

The role of cytoplasm in adaptation. In organizing the experimental results from the transplant gardens, increasing scope has been given to methods dealing with the nature of fixity and fixation as involved in adaptation. Considerable evidence has accumulated during the years to indicate

that these properties are functions of the cytoplasm, and the transplant technique has been expanded to focus primarily on this problem. The most important method concerned is that of simple and double returns of adapted materials to the original habitat. Next in importance is the application of fertilizer both to transplant beds and to natural quadrats of a species, to bring about overgrowth with its specialized effects. Tall and small individuals have been utilized in the case of most alpine species, and these in turn have been subjected to dosages of fertilizer. Alpine species have been transplanted reciprocally along an altitude transect with gardens at 12,000, 13,000, and 14,000 feet, and special measures have been taken to break the extreme dwarf habit of ecads from the summit of Pikes Peak.

Practically all climatic and most edaphic ecads bear the imprint of the season to a certain degree, in addition to that of the particular habitat. This is particularly true when the year is marked by extremes of dry or wet, in which case the forms in any one spot are to be regarded as seasonal ecads. These have a direct bearing not merely on fluctuating adaptation, but especially also on the selection of strains for breeding and on the performance of these when the progeny is returned to the range. The seasonal effects must be discounted at both ends of the process, and this can best be done by transplanting into a series of climatic habitats, as has been proposed in connection with the problem of regrassing. In consequence, a special investigation is being made of the adaptation of climax grasses and sedges of the mixed prairie at intervals of 1000 feet from an altitude of 5000 to 10,000 feet, and this is supplemented by transplanting them into the Plains Garden at 6000 and the Montane and Alpine gardens at 8500 and 12,000 feet.

In addition to the first volume, already issued, which deals with adaptation in coastal dunes at Santa Barbara, the three remaining ones of the adaptation series will appear as promptly as possible in the course of the next year or two. The second volume will give an account of adaptation under control in some fifteen garden habitats at Santa Barbara, and the third will deal with the response to climatic and edaphic conditions in the score or more of natural gardens of the transplant transect on Pikes Peak. The fourth and final one will treat of the convergence and conversion of species at both centers, and of the ecological basis of evolution and hence of classification and the natural system.

CLIMATE, CLIMAX, AND CONSERVATION

F. E. CLEMENTS AND E. S. CLEMENTS

Local and regional compensations for climate. The rapidly growing recognition of the basic nature of vegetation in connection with the problems of conservation has made an adequate understanding of dynamic ecology indispensable to both conservation research and practice. The mosaic of communities and the varying structure within a community have obscured the essential unity and made difficult the tracing of organic relationships. This situation has been aggravated by the natural tendency to treat each unit as though it were static and hence unchanging, if not unchangeable. The term climax has been frequently and variously misapplied, until in the hands of many users it is misleading or meaningless. The insight and clarity originally gained by its employment have too often been confused or lost and can be recaptured only by a more scientific sense of values. Fortunately, this task is much easier than it seems if the methods of dynamic ecology are applied to it consistently.

In spite of its apparent complexity, all

the vegetation of the globe consists merely of climaxes and modifications of these. Moreover, the modifications, innumerable as they appear in detail, are of but two sorts. The more familiar kind comprises the communities or stages that mark succession, such as those of ponds, reed swamps, dunes, and abandoned fields. In their earlier stages these give the appearance of being independent of climate; they occur in different climaxes, and it is only as they approach the final stages that their organic relation to the climax becomes evident. The other and more puzzling type of community shows no successional movement or structure and passes readily enough for an intrinsic part of the climax proper. Nearly always, however, it is set apart by differences in life form and hence in physiognomy or appearance, as well as by essential features of the habitat. It is the latter in particular that furnish the explanation of these alien communities, many of which are relicts of former climaxes entrapped by widespread changes of climate. In short, they have been able to survive in spite of the latter by virtue of some form of compensation afforded by the local conditions. Under disturbances induced by man, they may even spread over wide areas and simulate an actual climax so closely as to be considered such by static criteria. Together with other disturbance types they are designated as pro-climaxes, i.e., false climaxes, because they can persist only so long as some compensating process or factor offsets the normal control by the climax climate.

In general, the chief factor concerned in compensation for an unfavorable climate is water content or holard, though temperature has a role in higher latitudes and altitudes. The initial adjustment, however, is brought about by some feature of topography or soil, or by such processes as destruction and competition. Temporary

compensation in terms of years or longer periods may be effected by the favorable phase of climatic cycles of different intensity and duration. The major topographic controls are the valleys provided by crustal movement or dissection, slope exposure as found on hills, ridges, valley walls, etc., and altitude, especially where ecotones are involved. The processes acting as intermediaries are the movement of water over the surface to furnish run-in or water table within reach of roots, and the changed incidence of radiant energy exerted primarily through evaporation and transpiration, with accompanying alterations of soil temperature.

Soils afford refuges in proportion as they conserve water for plant use through ready absorption, slow evaporation, and low echard or nonavailable water. These qualities are possessed in the first degree by dune sands and diminish steadily with the reduction of the sand fraction toward the finer loams. Escarpments are complexes of topographic features and soil differences, the talus slopes being mixtures of rocks, immature soil, and pockets of finer material. Infiltration is good and the available water usually high, but the characteristic feature is the irregular surface, which imposes wide spacing of plants and thus reduces competition. Furthermore, the poorly consolidated soil favors the root systems of trees and shrubs and discourages the invasion of grasses with their fibrous roots and preference for deep soils.

Finally, compensation may enter the climax pattern wherever the removal of plants or plant parts by any agent becomes a significant process. The ability of the affected species or group to secure its normal requirement of water and nutrients is reduced, to the advantage of those not eaten or destroyed. To a corresponding extent the latter prosper under the modified habitat and become the dominants,

not of a climax, but of a new community that replaces it more or less completely, namely, a proclimax due to disturbance and hence termed a disclimax. All such dominants must have been present, in small number at least, when the process of disturbance began, but little or no account was taken of them until dynamic ecology initiated its inquiry into the causes of change. In this connection, however, it is necessary to recognize that the favored species may have been original members of the climax, as in the cases of the short grasses, or they may have been aliens introduced through settlement. Such transformations have followed civilized man wherever he has gone, but he has been unmindful of them until the process has become all but irreversible. This aspect of the changes wrought in the climax by human disturbance and their readjustment to climate under proper utilization are considered in the next section.

Disclimates, eradication, and regrassing. Disclimates are developed in all climates whenever effective and extensive disturbance persists or recurs at short periods. They are as universal as man and are all but impossible under natural conditions, persistent subclimates due to lightning fires forming perhaps the sole exception. They occur in all types of vegetation, forest, scrub, and grassland, but for a number of reasons are most varied and significant in the latter. The two chief reasons are that grass climates can be modified in more ways without being destroyed and that the dominance or abundance of the grasses is readily obscured by the more conspicuous shrubs or trees. Moreover, the grassland climax is the most extensive type of vegetation on the North American continent and hence lies in contact with the largest number of communities ready to invade it at the first sign of disturbance.

Disclimates may be conveniently ar-

ranged in two groups, namely, those in which grasses or forbs give the character to the new community, and those in which this role is taken by shrubs or trees. In the first instance, the change may operate wholly within the group of climax grasses; these may be replaced by annual grasses or forbs of the climax, or completely dispossessed except in protected spots by alien annuals, chiefly grasses. The first type develops when overgrazing removes the mid grasses of the mixed prairie or reduces them to a subordinate role, thus producing a low cover of *Bouteloua*, *Buchloe*, *Carex*, and *Poa* in varying mixture. The first two genera are lacking in the Palouse prairie, where *Carex* and *Poa* occupy the intervals and spread as the mid grasses are eaten down or out. In the coastal prairie, *Bouteloua* and *Buchloe* are joined by the native *Hilaria* and the introduced *Cynodon* to produce a cover similar in essentials to the short grass of the Plains. For the most part, the true prairie lacks short grasses, though the buffalo grass has taken possession of pastures along its western edge. In the eastern part, however, where it lies in contact with the tall grasses, overgrazing and burning have given rise to a disclimax of *Andropogon*, *Chrysopogon*, etc.

The desert plains of the Southwest represent the only genuine short-grass climax. Introduced grasses find the climax habitat too arid, and the first consequence of overgrazing is the appearance of the "six weeks" grasses, which are native annuals of the genera *Aristida* and *Bouteloua*. The outstanding disclimax of alien annuals is to be found in California, where it has displaced the perennial bunch grasses during the past two centuries. The matrix is composed chiefly of *Avena*, *Bromus*, *Festuca*, and *Hordeum*, with *Erodium* and *Medicago* as Old World associates and a number of native annuals, especially of the

borage family. Within a generation, another brome, *Bromus tectorum*, has swept over the Great Basin, to form the typical annual disclimax of the Palouse grassland, particularly in the Transition area. Extensive disclimates of forbs alone are altogether exceptional, but an important example of this occurs in central Texas, where poisonous bitterweed (*Actinia odorata*) constitutes a unique problem in eradication. Abandoned fields may remain in the weed stage for a number of years and thus simulate a disclimax, but they later pass through the stages of the subsere to merge into the climax, unless a new abandonment intervenes.

Probably the most dramatic type of disclimax is that formed of sagebrush and saltbush, largely because of its vast extent and high visibility. The desert scrub of the Southwest takes a similar part; one of its component species, the mesquite, rivals the sagebrush in area and in the tree form exceeds it in verisimilitude. It is readily understood how these were inevitably mistaken for true climates in the early days of dynamic ecology, but such an opinion is now quite untenable, except for those who maintain a static viewpoint. All the sources of evidence, observational, historical, theoretical, and experimental, are in accord as to the origin of these disclimates, and their reconversion into grassland on an increasing scale integrates the various kinds of proof.

The sagebrush of the Great Basin is much the most important community of this type, but the coastal sagebrush of California is a related disturbance type with similar relations to grassland. Over much of Nevada and Utah, *Artemisia* is largely replaced by such halophiles as *Atriplex* and *Grayia* without essential alteration of the nature of the disclimax. In the Southwest a like alternation exists between *Covillea* and *Prosopis*, the creosote bush invading

the low, drier grasslands and the mesquite the higher and easterly moister districts. Finally, there are a number of low shrubs a foot or two high that behave in the same fashion, such as *Chrysothamnus*, *Gutierrezia*, and *Haplopappus*, but the areas concerned are small and local, and stature discourages the assumption of a climax.

The most important disclimates of the tree life form have for the major dominant mesquite, juniper, or aspen. All these may assume the shrub form and regularly do so under less favorable conditions. In its optimum state, mesquite occurs in southern Texas and adjacent Mexico, where individuals may reach a height of 40 to 50 feet with trunks as much as 2 feet in diameter. The canopy is more or less closed and few of the original grasses survive beneath it. By contrast, juniper is found chiefly in the form of "cedar brakes," which is a somewhat open savanna, varied by denser groups or "mottes," often of oaks also. The aspen parkland of the North, on the other hand, shows a primary pattern of small closed groves with a central nucleus of older, taller trees. Actual savanna is less common and usually finds expression in a rolling topography or on sandy soils. Finally, oak woodland or chaparral may be converted locally into a disclimax by burning and browsing, and a special form of this, the so-called shinnery, occurs in sand throughout the southern Great Plains.

In conformity with their origin and nature, all disclimates are reversible, that is, they can be changed back into the proper climax wherever dominants of the latter persist in sufficient quantity. This is the general rule and serves to emphasize the fact that much more land can be returned quickly and cheaply to grass by the conversion of disclimates than by any other method. This applies especially to the woody types, in which the removal of the shrubs or trees is essential. In disturbed

grassland, the species in possession have usually become an intrinsic part of the grazing economy of the region and need only to be supplemented in an adequate manner. If, however, a poisonous or otherwise injurious species is in almost complete occupation, eradication is as imperative as with woody invaders.

Three primary methods are available for the direct eradication of sagebrush, mesquite, juniper, and similar undesirable indicators of overgrazing. In addition, there are the measures concerned in regulation and management, such as rest, rotation, and deferment, which in general are too slow to be practicable.

Like these, mowing depends on the gradual outcome of a readjusted competition between grasses and shrubs. It is indicated when the latter produce root sprouts and have stems sufficiently thin to permit cutting with a mower bar of special type. For nonsprouting species, such as the basin sagebrush and most junipers, burning is the most rapid and economical device, though it must be practiced under an experienced eye, both for safety and for optimum results. The critical task is to secure a fire that will run and yet produce a moderate burn, sufficient to kill sagebrush or cedar with little or no injury to the grass crowns. Time of year, condition of the soil, and direction and velocity of the wind are all elements in successful burning, designed to insure prompt and adequate regeneration of the climax grasses.

Mechanical means of eradication embrace hand grubbing, "railing," "blading," and tractor-drawn "dozers" that push the trees over and uproot them. Grubbing is practically out of the question because of costs, except when a large body of public labor is available. Railing is the cheapest and most rapid of methods with low shrubs and cacti, but lacks something in

thoroughness in comparison with blading, which is more expensive, at least in initial equipment. In dense climax-like stands of mesquite on relatively level terrain, the dozer method as developed on the great King Ranch in southern Texas is unrivaled. In order to justify the higher expense, it is necessary to seed the cleared areas to such a species as Rhodes grass (*Chloris gayana*), which has exceptional productivity. In savanna stands of shrubby mesquite, smaller dozers can be operated with such economy as to warrant a year or two of waiting for the climax stand of grasses to redevelop. The use of chemicals such as sodium chlorate has not proved successful, but the injection of arsenites and fuel oils gives promise of satisfactory results under certain conditions.

A decision as to the desirability or necessity of artificial seeding after eradication rests on a number of points. The first of these is the abundance of the climax or other desirable species, which is directly related to the length of time needed to reproduce a cover that can be safely utilized. This must also be considered in the light of reserve pastures or supplementary forage that may be available, or the possibility of reducing the rate of stocking during the period of regeneration. As a rule, such adjustments are limited in scope, and it is essential to bring the range again into use within a period of two or three years. In many areas of sagebrush climax, the grasses are still sufficiently abundant so that a usable cover can be established in a single year, by skillful burning during a favorable season. Similar good results have been secured by light burning in juniper savanna. Heavy infestations of cacti require several years after railing or blading, and this will apparently prove true of mowed areas in sand sage.

Recovery in savanna of shrubby mesquite is usually rapid where overuse has not

been serious, but in the canopy stands mentioned earlier, it is too slow to be considered. Except for occasional openings, shade and competition have reduced the grass stand both in species and in individuals to the point where natural regeneration is wholly uneconomic. Even when the climax grasses return more promptly, they are mostly short grasses for some time and hence may produce but a small part of the forage yielded by an introduced mid grass such as *Chloris gayana*. Rhodes grass, however, is adapted only to a warm-moist climate, and recourse must be had to the native species of this genus in central Texas and northward. Probably no other species equals *gayana* for regressing within its climatic limits, but a cold-temperate plant of similar capabilities is crested wheat grass (*Agropyrum cristatum*), which is the mainstay for seeding abandoned lands in the northern United States and Canada. It will doubtless prove successful in sagebrush clearings where relict grasses are sparse, in the Northwest especially, and it is being tested beside the most promising native species by means of experimental grids.

Origin and decadence of a climax. By comparison with forest and grassland, the climaxes in which the life form is the shrub or small tree have undergone marked reduction and fragmentation during major climatic shifts toward dryness. This is due to their relatively narrower range of adaptation and to a lesser capacity for successful competition with tree or grass in the shifting ecotone between them. The four communities involved are the pinyon-juniper woodland, the oak-chamise chaparral, the sagebrush, and the desert scrub. Each of these has been assumed to be in a state of transition in which some part of the original climax still persists. The situation today may be illustrated by the woodland, of which the half or more at lower

altitudes consists of a juniper savanna, now largely converted into a disclimax through overgrazing. An approximate fourth is a taller, less open savanna of pinyon and juniper, and at the higher altitudes the height and density of the two dominants afford a canopy that shades out the invaders from the mixed prairie. Chaparral remains largely climax in nature in California, but is practically all savanna along the central and southern Rockies. In the true deserts, such as Death Valley, Mohave, Colorado, and Sonoran, the desert scrub is climax, but its wide extension from central Arizona to western Texas is today a disclimax formed from the desert plains grassland.

The rank of the sagebrush has been more doubtful. Though this was regarded in the beginning as climax over most of its great extent, continuous field study for a quarter of a century had shrunken its possible climax area within the state of Nevada and finally to the central part. The advent of exceptional rainfall in the spring of 1941 provided a unique opportunity for evaluating its role in this region, as a consequence of the seasonal compensation for overgrazing mentioned on an earlier page. This has not only furnished a clearer and more accurate picture of the proper relations between the climax grasses and the disclimax shrubs, but has also permitted in much detail the reconstruction of the composition and structure of the original grassland. The outcome was to leave no doubt of the disclimax nature of the sagebrush, *Artemisia*, *Atriplex*, *Grayia*, and their associates, but it further revealed the fact that two different associations of the grassland climax were concerned. The Palouse Transition, with *Agropyrum*, *Poa*, *Stipa*, *Koeleria*, *Festuca*, etc., extends across the state to about the middle line, where they are gradually replaced by *Hilaria*, *Bouteloua*, *Muhlenbergia*, etc., of the mixed

prairie. The various dominants of the sagebrush continue, however, through the two grass communities, dropping out only in the southern part where the desert scrub makes its appearance.

The sagebrush exemplifies the universal rule as to the simultaneous evolution of species and community through adaptation to a changing climate. The primitive section of the genus *Artemisia* is *Abrotanum*, which is circumpolar and contains by far the largest number of species and subspecies, nearly all perennial forbs. Many of these, and notably the highly adaptable *A. vulgaris*, moved southward into the Southwest and adjacent Mexico during a major cool-moist phase, where some responded to a subtropical climate by becoming woody shrubs. The parent stock of these is best represented by *A. californica*, though it must have given rise also to *tridentata* in the center and *filifolia* to the eastward. Under the compulsion of the next reversal of climate, these migrated northward, *californica* along the Pacific Coast region, *tridentata* in the warm-arid Great Basin or northern British Columbia, and *filifolia* to the north Plains. Without

going into the detailed evidence, it is a fair assumption that each of these became the major dominant of a climax sagebrush association. With a return to cool-moist conditions, these slowly retreated to the south and were replaced by prairie. But each of them survived within the climax grassland where adequate compensation could be found. In California, this was on the flanks of the Coast Ranges; in the Great Basin it was on slopes, and in escarpments and valleys; and in the Plains region it was in dunes, sandhills, and sandy wastes. At the opening of the period of settlement, practically all the land below the montane zone of the many ranges was grassland, with sagebrush relicts of the respective associations limited to the refuges indicated. This was still the situation in the John Day Valley of Oregon, for example, in the early nineties. With the multiplication of herds began the era of overgrazing, and the sagebrush began to move out of the relict areas, first slowly and then with increasing rapidity, until in little more than two decades it became the apparent climax, with the air of having always been in possession of the West.

PALEOBOTANY

RALPH W. CHANEY

The past quarter-century has been spent in a systematic study of the Tertiary floras of western North America. This study has been concerned not only with the determination and description of the plants of the past, but with a detailed comparison of groups of fossils with forests of today. Since many living forests show close relationships to fossil assemblages, an interpretation of the Tertiary record through inferences from modern vegetation becomes a means of reconstructing the earth's surface during various stages of later geologic history. The climate and topography

of the Tertiary, and their progressive changes down to the present, may probably be more accurately judged by such analyses of fossil floras than in any other manner.

The record of Tertiary vegetation is more complete in the John Day Basin of eastern Oregon than in any other part of western America. This region is centrally located with reference to other fossil localities in adjacent states, and its floral sequence therefore provides a basis for comparison and correlation over a wide area on the Columbia Plateau and in the Great Basin. Fossil floras similar to those of the

John Day Basin have been found in other parts of Oregon, and in California, Nevada, Idaho, and Washington. The Tertiary vegetation of Alaska, Eurasia, and the arctic islands likewise shows marked similarities. Mammalian faunas occur in close association with plant-bearing deposits in the John Day Basin, providing a basis for checking their age and succession. The absence of the sea from the interior of Oregon since the Cretaceous period has made it impossible to use marine invertebrate faunas for corresponding study and comparison.

The writer and his associates have described and discussed numerous floras from beds of Tertiary age in western North America, and from deposits of Cretaceous age which indicate ancestral relationships. Other students have contributed to the study of past vegetation in this region, and the character and sequence of forests is now relatively well known for these later chapters of earth history. Having in mind the fundamental significance of the floras of the John Day Basin, we have recently undertaken their restudy and summarization. Three floral units are well represented and available for additional extensive collecting: (1) the Mascall flora, of Upper Miocene age, is typically temperate in aspect, with a mixed deciduous composition resembling that of forests now living in the eastern United States and northeastern Asia; (2) the somewhat older Bridge Creek flora also has a conspicuous representation of genera now restricted on this continent to the area east of the Rockies, and in addition has a dominant element related to the coast redwood forest of California; (3) the Clarno flora, dating back to the Upper Eocene, differs from these younger units in its predominance of plants no longer living in temperate regions; like most Eocene floras from middle

latitudes in North America, the Clarno forest was subtropical in character, with many genera now confined to lower latitudes. The Mascall flora is being studied first, to be followed by the Bridge Creek and Clarno floras. Consideration will also be given to several smaller units which have a bearing on the problem of floral development, notably to those of Pliocene age, which are now represented by relatively inadequate collections.

The first step in our summary study of the Mascall flora has been the collection of approximately nine thousand specimens from localities near Dayville. Supplementary collections of somewhat smaller size have been made in areas to the east and south, near Austin and Burns. The field study of this material has involved a recorded count of the number of specimens of each species represented. Preliminary analysis of these statistical data indicates that the Mascall forest was variable in composition over short distances, probably largely as a result of local differences in topography. The living forest of the Allegheny Plateau shows similar variability in regions of topographic diversity. A close resemblance is apparent between these two forests, separated by thousands of miles and millions of years, with hickory, elm, maples, and oaks among the more common trees in each. Similarities between the Mascall flora and the lowland forest of the Gulf states are suggested by the abundant representation in each of the swamp cypress. *Sequoia* twigs are less numerous in the fossil record, but their occurrence along with the Tertiary equivalents of several species now associated with the coast redwood indicates the survival of this Mascall element on the present coast of California. Composite in aspect, with resemblances to several widely scattered assemblages, this Miocene forest differed

from any living forest of Oregon in its dominance of broad-leaved deciduous genera. We may confidently assume that the climate in western America during the Miocene was characterized by rainfall well distributed throughout the year, as is the case where such genera are most typically developed at the present time. It is apparent that our final interpretation of the Mascall flora—the reconstruction of the terrane over which it spread, and of the climate which characterized this now semiarid region—must depend on a comparative study of several living forests which represent the modern differentiates of Tertiary vegetation.

The Mascall formation as now defined is limited to the John Day Basin, but deposits containing a similar floral assemblage have been traced eastward into the Blue Mountains, and thence southeastward into Idaho. As mentioned in last year's report (Year Book No. 39, p. 176), beds containing an equivalent flora have recently been studied in Harney County, south of the John Day Basin. The relationship of the Mascall formation to the Latah formation of Washington and northern Idaho has often been suggested, and will be further considered during the field season of 1941.

These deposits, comprising tuff, ash, and volcanic sands and gravels, represent the accumulation of pyroclastic and reworked sediments along the flanks of the volcanoes which were becoming so conspicuous a part of the landscape in the Northwest during the Miocene epoch. From their linear distribution, it is supposed that some of these volcanic sediments were laid down in valleys. The leaf-bearing shales are interpreted in all cases as lake deposits in basins of small size. The explosive vulcanism which produced the Mascall and related materials seems to have been closely associated with the extrusion of great sheets of Columbia River basalt. In most or all

of the areas above mentioned, these relatively unindurated volcanic sediments have been protected from erosion by capping flows of basalt which poured out at or near the close of this extrusive episode, an episode during which the present topography of the Northwest interior was largely established.

Similar events in Tertiary history, though dated somewhat earlier than those of the Mascall, are under study by Harry D. MacGinitie at Florissant, in central Colorado. Extensively collected for many years, the abundant and diversified Florissant flora has been thoroughly revised by Dr. MacGinitie with the aid of comprehensive new collections. The flora contains two elements, one from the forest which occupied the lake borders, the other from drier adjacent slopes. Field work, including geologic investigations of the structure and areal distribution of the plant-bearing beds, is being concluded during the season of 1941.

The studies of Daniel I. Axelrod on the Pliocene vegetation of California and Nevada throw significant light on trends in floral development since Miocene time. The gradual modification of the mesic forests of the Middle Tertiary in response to increasing aridity, and their gradual displacement by semiarid woodland vegetation before the close of the Pliocene epoch, give a sound basis for understanding the origin and distribution of modern woodlands in the more arid parts of the western United States and Mexico. Several short papers by Dr. Axelrod have been published, as listed in the bibliography.

Continued investigations by Erling Dorf in the Upper Cretaceous of Wyoming, Colorado, Montana, and the Dakotas have added in an important way to our knowledge of the ancestors of Tertiary trees. A report on the flora of the Lance formation

of eastern Wyoming has been completed. Work has progressed on collections from the Hunter Canyon formation of Colorado,

the Mesaverde group of southwestern Wyoming, and the Hell Creek formation of Montana and the Dakotas.

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DEPARTMENT OF EMBRYOLOGY

Baltimore, Maryland

GEORGE W. CORNER, *Director*

PROGRAM OF THE DEPARTMENT

Because of retirements and the drafts made upon our group by universities, we begin the fall of 1941 with a staff of investigators of whom five (out of seven) have been appointed within the past eighteen months. It goes without saying that the new workers who have stepped forward to fill the gaps have not been chosen, nor have they consented to join us, without full consideration of the tasks and opportunities afforded by this laboratory. It is appropriate, therefore, to set forth at this time, as clearly as possible, the nature of our work as we see it.

Let us begin by admitting that a program of scientific investigation cannot be planned in advance in intimate detail, any more than a military campaign. Obstacles cannot always be overwhelmed by frontal attack, they must often be outflanked. Reserve forces must be awaited; new weapons must be forged, even invented to meet new conditions. The army knows its general objectives, but must reach them as best it can, modifying the campaign whenever necessary to fit the terrain or to meet some unforeseen situation.

The past history of this Department, looked at from one point of view, is a brilliant example of a planned campaign, systematically conducted. It is indeed remarkable how many of the items of Dr. Mall's original "Plea for an Institute of Human Embryology" have been successfully executed. On the other hand, a list of the individual investigations mentioned in the successive Year Books might suggest that the advance was not always direct.

What has been done has at times not even been embryology under standard definitions of the term, reminding us indeed of an American scientist who in answer to a query defined his branch of science—pharmacology—as "anything done by a pharmacologist." Yet the general result has been an advance in our knowledge of embryology in the strict sense.

The dictionaries define embryology as the study of the development of the individual from the egg to the adult stage, in plants and animals.

This immense field of study may be subdivided in various ways; for example, according to the methods or instruments of investigation, into morphology, experimental embryology, histogenesis, physiology of the embryo (including chemical embryology), physiology of reproduction, genesis of behavior (i.e., of nervous responses), anthropometry of the fetus (growth, proportions, racial characteristics), etc. It may be divided also according to the kind of organism studied, e.g., embryology of plants, of invertebrate animals, of vertebrates, of mammals, of man. Normal embryology may be studied as versus abnormal (i.e., teratology and the pathology of the embryo). There are specialists who subdivide by organs and take one or more of the viscera for their private field, e.g., the heart, the brain, or the lung.

Our Department has never attempted to cover the whole of this broad field. Indeed, the original plan emphasized the embryology of the human species as its prime interest, and the first grants were

made because it was clear that this one part of the subject is of the greatest importance for mankind, but requires special methods of collection and study, and special care of the scarce and precious material. The Department grew out of the work of a professor and his department in a medical school; both of the subsequent directors were trained as physicians; and the Department has maintained very close relations with the medical profession. Other branches of the science either require much less specialized effort and equipment, or use material that is generally available (e.g., chick embryos), or can be prosecuted more profitably elsewhere by workers trained in zoology rather than in the medical sciences (embryology of the invertebrates, for example).

The study of human embryology remains our primary task; but this is no narrow or limited undertaking. Dr. Mall saw as immediate objectives study of the anatomy of the human embryo at various stages, the curve of growth and the anthropometry of the embryo, the development of certain especially important organs (especially the brain), the development of the various special tissues (histogenesis), the study of sterility, the causes of abnormalities and monstrosities, and (a major undertaking by itself alone!) comparative and experimental embryology to elucidate the human. In execution of this program, the Department has gathered a considerable collection of human embryos. The specimens, and the numerous models which have been constructed from them, serve as a working museum and as a kind of Bureau of Standards, which will have value as long as embryological investigators need to control their opinions by resorting to original material. Many studies have already been made on the form and general development of the human embryo from the eleventh day on. The collection is

already the largest and most important in the world, but it is by no means so complete as it could and should be made.

The work on histogenesis, led by Dr. Warren Lewis and Dr. Margaret Lewis, contributed much to embryology in the strict sense, but led the workers off into a fundamentally important field not thought of by Dr. Mall as part of his program, namely, the study of malignant tumors.

In the field of comparative embryology, it was thought advisable to open up the study of the rhesus monkey, the highest primate readily available for planned collection of early embryos. Dr. Hartman, who undertook this project, found that in order to get the embryos he had to spend years studying the menstrual cycle and other aspects of the physiology of reproduction—another good example of the way a program of investigation inevitably shifts its orbit. By reason of these apparently collateral studies, not only has ideal embryological material been obtained, but, what is even more important, a great advance has been made in determining the age and rate of development of such specimens.

With regard to problems of pathology, such as those of human sterility and the causation of fetal abnormalities, it turns out that they are even more complex and difficult than could have been supposed thirty years ago. The degree to which they can be studied by direct examination of human embryos was overestimated. Their solution will involve genetics, biochemistry, and endocrinology, and they demand experimental attack, using laboratory animals. If such questions are a legitimate concern of such a laboratory as ours, we are going to find ourselves involved from time to time in considerations and methods not strictly embryological in the original conception of that science.

Experimental embryology, in the sense intended by Dr. Mall in his prospectus—that is, the study of development by operative and other interference with the embryo—did not develop here, partly because other interests pushed it aside, and partly because it had to be carried on with salamanders and bird embryos and hence was somewhat removed from the general trend of the laboratory's program, with its emphasis on man and higher animals. This important branch of the science was already being developed elsewhere, notably at Yale by Dr. Ross G. Harrison, a former associate of Dr. Mall. Now that ways and means of studying the development of experimental embryology in mammals are being found, there is every reason to develop that subdivision here, but this matter will be discussed again later in this report.

In a very recent statement entitled "Changes in the trend of embryologic research," Dr. Streeter (see appended bibliography) points out that the work of the geneticists, of the students of cellular growth in tissue culture, and of the experimental embryologists has changed the trend of embryology. The primary aim had been to work out the pattern of development, and to compare the patterns of various kinds of animals, with the hope of discovering the basic morphological plan. The experimental work of recent decades has emphasized the transformations of structure rather than the momentary pattern at any one stage, and has called attention to the mechanisms by which these changes are controlled and development is determined, namely, by genetic and environmental factors (both internal and external) such as genes, "organizers," hormones, and metabolic processes. To quote Dr. Streeter: "As these discoveries became available to the embryologist, he has found that a more satisfactory analysis of development can

be made than the classic one of the past which was based almost entirely on an artificial morphologic ground plan. The embryo, with the opportunities now existing, can be studied as a functional organism and the activities of its constituent cells can in large part be determined. . . . The present trend in embryology is thus to regard all parts of the embryo and its auxiliary tissues as having functions to perform. . . . It is now realized that the embryo at all stages is a living individual, and is to be explained as a biologic problem, rather than an exercise in purely morphologic abstraction."

Fortunately, the sciences of physics and chemistry are coming ever closer to biology. Methods of detecting chemical substances in the tissues and tracing their movements, and ways of measuring the processes of oxygen exchange, secretion, and excretion are becoming available and will undoubtedly advance rapidly. The means by which to study embryology as a biological problem are more and more at hand.

In mammals, study of the embryo as a living, growing organism inevitably involves consideration of the whole environment of the embryo from the formation of the egg in the ovary to its attachment in the uterus, and on to the final separation of the infant from the mother at birth. This brings in the question of the structure of the ovary and uterus, and their changes during the reproductive cycle, or menstrual cycle as it is in higher primates. Such topics, not literally embryological and bordering on physiology, endocrinology, and neurology, have forced themselves upon us and have been earnestly studied, as will be seen from the "Contributions to Embryology" and other publications of our staff. It is in such border regions between two branches of science that progress is most likely to be made. Although our group has always been called simply the

Department of Embryology, discerning observers of its work are well aware that ever since its earlier years a more accurately descriptive title would have been Department of Embryology and the Physiology of Reproduction.

Our aims for the future do not differ greatly from those of earlier years when stated in general terms. Our object is to understand the development of the human embryo, using for that purpose whatever methods become useful, and extending our attention to other species as may be necessary and profitable. Because, however, so much progress has already been made in the morphological part of the field, an embryological laboratory will in the coming years inevitably call upon the methods of physiology, chemistry, and physics more than in the past.

Morphological embryology of man. Of all the items of Dr. Mall's original program, only one has come anywhere near realization, in the sense that the results can be summed up and written down, and further work along the same line begins to bring diminishing returns. This is the study of the morphology of the human embryo. The main outlines are known from about the tenth day on. Dr. Streeter is now compiling a monographic classification of the stages of human development which will mark the attainment of what Dr. Mall had in mind. Our great collection of embryos, models, photographs, and other records contains the basic material of this work. It is a permanently useful treasury of human morphology. It will be maintained, studied continuously, and added to as material becomes available. Dr. Chester H. Heuser, long engaged in this division of the laboratory, has been designated Curator of the Embryological Collection. Even now the collection is receiving additions, some of them equal in

importance to anything received in the past; in particular, the extremely early human embryos obtained by Dr. Hertig, of Boston, an accomplishment made possible by funds from the Carnegie Corporation of New York.

Implantation and placentation. These remarkable specimens and the many others of our collection of early embryos are of use not only in the study of the embryo itself, but equally in the study of the attachment (implantation) of the embryo in the uterus. Implantation varies greatly in detail from one species to another, and therefore it must be studied in human material as well as in other animals. In its normal aspect it has to do with the nutrition of the early embryo; in its abnormal aspect it is intimately concerned with degeneration and monstrosity of the embryo. In recent years the advance of knowledge of the ovarian hormones, particularly that of the corpus luteum, has given further insight into the problems of implantation and early placentation. Continued study of this field by direct examination of collected material, and by experiment, will certainly be a part of our program.

Other primate species. The study of embryos of other primate species, already well begun with the rhesus monkey material, should be extended to the anthropoid apes and to the American (platyrhine) monkeys. The present is not a favorable time to go far afield, but ways and means of obtaining such material will be sought. Our growing contacts with Spanish America should ultimately favor collection of platyrhine embryos.

Histogenesis and organogenesis. The morphological embryology of man and mammals in general is of course far from complete. Much is to be done with regard to the detailed development of certain organs and systems. Those of especial

interest for us are the nervous system and the reproductive system, both of which differ greatly in man and the other primates from the general mammalian plan. Problems of the embryology of the reproductive system are now being studied by Dr. R. K. Burns, Jr. It is interesting to note that in this field experimental methods, such as modification of development by treatment of the embryo with hormones, promise to yield more for the time being than direct study of normal material.

With regard to the nervous system, of which no very extensive embryological investigation has been made here since Dr. Streeter's important contributions were made some years ago, recent advances in knowledge of the behavior of the mammalian, even of the human, embryo, i.e. the responses of nervous and muscular systems to external stimuli, have created great interest in the development of the nervous system. This kind of investigation is being well done elsewhere, but the subject is large, and if at any time it should become possible to consider a good-sized addition to our efforts, it might well become our duty to undertake renewed study of the development of nerve cells, nuclei, and fiber tracts within the brain and spinal cord, combining the most advanced methods of preparation with the special techniques of photography and reconstruction that have been developed here. This topic is mentioned to emphasize the point that the embryological collection will in the future most profitably be extended in special departments, i.e. very early human embryos, material from special regions especially prepared, or material from infra-human primates or other species of particular interest.

Experimental embryology. As stated above, the application of experimental methods to mammalian embryos is now becoming possible. One of the most

promising means of attack is by use of marsupial animals, in which the pouch young, which practically speaking are embryos, can be handled directly and subjected to experimental treatment. The field seems unlimited in its possibilities. We have installed during the past year facilities for keeping opossums in the laboratory. Dr. Burns is already at work, using these animals in his studies of the development of the reproductive system as illuminated by the effects of ovarian and testicular hormones on the embryo.

It seems good generalship to limit ourselves in this laboratory at present to experimental embryology of the mammal, leaving the general subject to other laboratories. This voluntary limitation is all the more advisable since the Department of Zoology of the Johns Hopkins University, which is bound to be in close relations with us, has embarked under its new head, Professor B. H. Willier, on an intensive program of experimental embryology, using especially the chick embryo.

Chemistry of the embryo. The study of what might be called chemical embryology has received in recent years a new tool for research, namely, the use of "tracer elements" such as radioactive isotopes and heavy water. It is not too much to hope that in the future a great deal can be learned about chemical interchanges in the embryo and its environment, as the application of these substances is developed and particularly as it becomes possible to build them into compounds of biological importance. Meanwhile it is already possible to use them effectively to solve important embryological problems. Under Dr. Flexner's leadership, the passage of radioactive sodium and heavy water through the placenta and their distribution among the fetuses are being measured. This work will be greatly facilitated by the completion of the cyclotron at Washington. It

opens an endless vista of progress in chemical embryology.

Physiology of reproduction. Although a great deal of progress in the physiology of reproduction has been made in this and other laboratories, there is much yet to be done. The problems associated with the menstrual cycle and its endocrine relationships are largely unsolved; we do not even understand the fundamental mechanism of the menstrual changes in the uterus. The approach to these questions is now largely through physiological experimentation on rhesus monkeys (the only menstruating animals readily available for experiment) and also on the non-menstruating animals for the sake of comparison. The cyclic changes in the ovary, now well known in the lower animals and fairly well worked out on the monkey, should be studied in human material, and it is to be hoped that the prestige of the Department and the existence of a corps of physicians and surgeons who have helped build up the collection of embryos will favor the collection of material from the human reproductive tract for special study of the cyclic changes. These and other physiological problems relating to the state of affairs in the ovaries and uterus during gestation will have the attention of the Director and of Dr. Reynolds, who has joined us.

One more change in the staff of the Department of Embryology must be added to those reported last year. Dr. Carl G. Hartman, Research Associate since 1925, has been called to direct the Department of Zoology of the University of Illinois, and will leave us September 1, 1941. Dr. Hartman joined the Department of Embryology with the primary intention of studying the development of the rhesus monkey. To this task he brought unbounded determination and energy, suffi-

cient to carry him through long years in which he had to prepare for his main task by working out the general physiology of reproduction in this species, in order to find out how to obtain and how to diagnose pregnancy. These studies have been useful far beyond their original purpose, for they have helped us understand the reproductive cycle in all primates, and especially in the human female. Dr. Hartman's achievements have been fully reported in sixteen successive Year Books, but no documentary statement can tell how largely he has contributed to the work of the laboratory and of the Johns Hopkins Medical School and Hospital by his unselfish, enthusiastic cooperation in every project that might profit by his knowledge and talents.

Meanwhile the program of working out the embryology of the monkey has yielded all that was hoped, and more. The embryos and ova which Dr. Hartman finally learned how to obtain almost to order have been prepared by Dr. Heuser and the technical staff of the Department and studied by Drs. Streeter, Heuser, and Hartman with eminent success; and what is more, they have greatly contributed to better understanding of the early human embryo. Though we cannot say of Dr. Hartman's original project (any more than of any other investigative program) that it is finished, yet one can state that he has succeeded, better than most scientists are privileged to succeed, in realizing an ambitious and important aim.

In the study of animal reproduction, even more than in other branches of biology, questions of function are intimately associated with questions of morphological structure. The tissues and glands with which we are concerned are not building amorphous chemical secretions (like, for instance, the digestive

glands), nor are they producing intangible changes of potential, like the nerve cells. They are operating to create the embryo, a thing most definitely structural. However physiological, even chemical or physical, our present projects may seem, they are intimately based on the understanding of the form and structure of the embryo, its protecting membranes and attachments, and its surrounding and supporting organs (uterus and ovaries). It is our task to find out how this complex of interrelated tissues is constructed and also how it works. To that end we have used, and

shall have to go on using, the microscope, the microtome, the hypodermic syringe, the anthropometrist's calipers, and the paraphernalia of the tissue culturist. Now we are bringing in the opossum, the kymograph, and the Geiger counter. It is a fortunate thing that in this laboratory we are able to found our program on a sound basis of morphological knowledge and on a great treasury of anatomical material, and at the same time to utilize any new tools that may become available and to follow any promising path of investigation that may open before us.

SUMMARY OF INVESTIGATIONS, 1940-1941

EMBRYOLOGY

NATURE OF THE PRIMITIVE STREAK

At the autumn meeting (1940) of the National Academy of Sciences, Dr. Streeter presented an interpretation of a fundamental question of mammalian embryology, namely, the nature of the primitive streak, that median band of tissue prominently seen on the blastoderm of the bird embryo and readily identifiable also in the mammal. The primitive knot ("Hensen's node"), which is its forward termination, represents the mid-point of the dorsal lip of the blastopore, and the primitive streak itself is the equivalent of the more lateral parts of the anterior lip of the blastopore grown caudalward and fused into a line. The head process develops from the primitive node, the rest of the embryonic body from the primitive streak.

In view of its position on the surface of the embryonic shield, the primitive streak has usually been called ectodermal. Dr. Streeter has followed its actual history in the early macaque embryos of the Carnegie Collection. The point of his present contribution may be cited in his own

words: "The primitive streak is found to be in direct line from the primordial germplasm of the one-cell stage. In accepting the principle that development consists in proceeding from the more general to more specialized cells, the primitive streak is to be designated as the locus of the second order of such specialization, the first being when the auxiliary elements of the egg separate themselves from the true formative elements. The primitive streak in a strict sense is not ectoderm any more than was the original one-cell egg. From it, however, the primary embryonic tissues known as ectoderm, mesoderm and endoderm are derived. This step constitutes a second order in specialization, and the derived cells are therewith limited in their potentialities to their particular types of development. That is to say, the primitive streak is not a defined embryonic tissue but constitutes what remains of the primordial mother cytoplasm, changed only in being drained of the specialized cells that are moving out and away from it to fulfil their various limited careers."

This conclusion emphasizes Dr. Streeter's often repeated lesson that we must study the formative tissues of the embryo as living, differentiating material, and not label them prematurely according to a rigid diagram.

The lucidity and common sense of Dr. Streeter's statement gives it a deceptive appearance of being self-evident; but those who are familiar with the long effort to relate the early stages of the mammalian embryo with gastrulation in lower animals will realize how far the embryology of primates has gone when it becomes possible to analyze the primitive streak so clearly.

THE AMNIOTIC DUCT IN PRIMATES

At the 1941 meeting of the American Association of Anatomists Dr. Heuser demonstrated photographs and reconstructions showing the development of the amniotic duct in early human and monkey embryos.

There have been several reports of the occurrence in human embryos of a conical or ductlike projection of the amniotic cavity toward the chorion, recalling the amniotic duct of embryos such as those of rabbit and pig, in which the amnion forms by rolling up of the chorion over the embryonic area, as is usual in the amniotes, instead of by formation of a cavity by a split between the inner cell mass and the overlying trophoblast. Dr. Heuser finds that the amniotic duct is very frequently present in human and monkey embryos of about 10 to 18 days. He explains how it is produced by persistence of a connection between the roof of the amniotic cavity and that part of the trophoblast which overlies it. This is indeed the description of an embryological "missing link," for it has long seemed that among the mammals there are two quite different ways of arriving at the same end. Now we can see a fundamental similarity between the two methods. Dr.

Heuser's studies are being prepared for publication in full.

EPITHELIUM OF THE URINOGENITAL SINUS

During the past year Dr. Burns has completed construction of cages to house opossums for his work in experimental embryology in these mammals, and has continued his experimental program originally carried on at the University of Rochester. One important finding was published this year. Dr. Burns had previously found that estrogenic hormones, which characteristically produce hyperplasia and cornification of the lining of the vagina, when administered to young opossums during early pouch life produce extreme hyperplasia of the lining of the urinogenital sinus and of certain structures associated developmentally with the sinus. These associated structures are the neck and trigone of the bladder and the sinus horns (which subsequently contribute to the lateral vaginal canals). All the epithelium of these regions under the influence of estrogenic hormones comes to resemble closely that of the adult vagina at estrus. C. R. Moore, of Chicago, has reported similar results. Where other epithelia of the urinogenital tract join the sinus, the former do not respond, and the transition is abrupt.

This highly specific and sharply limited reaction to a particular kind of hormone suggests that all the tissues which so respond have a common origin from one embryonic source, namely, the ectodermal part of the cloaca. Dr. Burns explains on morphological grounds how the cloacal ectoderm is carried into the urinogenital sinus at an early stage, and shows from his experimental observations how it spreads on into the sinus horns and the bladder trigone. Only the bladder proper (exclusive of the trigone) remains lined by primitive cloacal endoderm.

The old problem of the extent of ecto-

dermal contribution to the urinogenital sinus is now clearly answered so far as the opossum is concerned. It should be reinvestigated in higher mammals. It will be noticed that in these experiments the estrogenic hormone has served as a tool for distinguishing tissues not otherwise readily delimited; just as certain cell types can be marked by their response to specific dyes, so cloacal ectoderm can be distinguished by forcing it to become cornified, prematurely, by the hormone.

ORIGIN OF THE RETE APPARATUS

There has been considerable difficulty as to the origin of the so-called rete apparatus, which in males becomes the rete testis, a network of tubules uniting the seminiferous tubules of the testis with the vas deferens. In females there are homologous structures which remain rudimentary. It has been suggested that the rete cords represent primitive nephrostomes. Dr. Burns finds that in his young opossums the manner of origin is especially clear. The most anterior rete cord is in continuity with the ostium of the Müllerian duct, with which it appears identical. The ostium and the rete invaginations are apparently homologous members of a series of primitive nephrostomes.

HETEROSEXUAL STRUCTURES IN THE FEMALE ALLIGATOR

Dr. T. R. Forbes, of the Johns Hopkins Anatomical Laboratory, has continued his studies on the reproductive system of the alligator, and in his sixth report describes a significant observation on the female reproductive system. It has been known for some time that in many reptiles the female retains rudimentary structures homologous to functional elements of the male reproductive tract. In particular, the mesoneph-

ric duct, which becomes the seminal duct (vas deferens) of the male, frequently persists in the female, but without function. Dr. Forbes has shown also that in alligators the posterior end of both ovaries is a "medullary rest"; that is, the medulla of the embryonic gonad, which in most animals disappears entirely or almost entirely when the gonad becomes an ovary, is partially retained in the alligator, forming a mass which is continuous with the functional part of the ovary, but which has decidedly male characters (in a rudimentary state of development), namely, absence of cortical tissue and presence of a testis-like stroma and tunic.

Now Dr. Forbes has followed the progress of these special structures by studying three females 32 to 38 inches in length, considerably older than those in which heterosexual structures had previously been described. He finds an advance in the direction of maleness; that is to say, the medullary rest, the system of rete tubules, the mesonephros, and the mesonephric duct were making a definite, if somewhat erratic, attempt to develop along the lines followed at a much earlier age by the testis and the homologous masculine accessory sex structures. It is very interesting, as Dr. Forbes points out, that this medullary rest and its potential excurrent system of rete canals and mesonephric duct strikingly resemble the rudimentary right ovary and its potential excurrent system in the fowl.

SEX RATIOS IN REPTILES

Dr. Forbes has noticed an apparent excess of females over males in alligators and has found reports indicating the same thing in turtles. He calls for careful observations by others on this question; for if it is confirmed, the unequal sex ratio cannot fail to provide an interesting question for study.

PLACENTAL FUNCTION

Dr. Louis B. Flexner has continued, with the assistance of Dr. H. A. Pohl, the studies on placental permeability first mentioned in last year's report. In these experiments radioactive sodium has been used as the "tracer." In one of their papers the investigators describe the design of an apparatus for detecting the radioactive material; it consists of a pressure ionization chamber connected to a delicate electrometer.

When the radioactive sodium chloride is injected into the veins of the pregnant guinea pig it is rapidly distributed through the tissues of the animal. Its concentration in the blood is practically in equilibrium with that of the body in 5 minutes. It takes, however, much longer to pass into the fetus than merely into the tissues of the mother. When the fetuses are of 60 g. weight or larger, equilibrium is reached in 5 to 7 hours.

The rate of transfer of sodium chloride across the placenta can be measured by taking out successive fetuses under anesthesia. The rate of transfer per unit weight of placenta makes a striking increase with advancing fetal age; at 62 days the transfer is about 10 times as fast as at 28 days. It is suggested that this increase in rate of transfer is associated with the known fact that in the guinea pig's placenta the chorionic epithelium thins out and almost disappears as pregnancy advances, thus reducing by one the layers between maternal and fetal circulations.

In a second paper the placenta of the cat is studied. In this species the time taken to distribute the radioactive sodium chloride between the maternal blood and maternal tissues is about the same as that determined in the guinea pig; but the time required to achieve equilibrium between mother and fetus, across the placenta, is much greater, i.e., 12 to 18 hours. This remarkable fact is in all probability connected with structural differences in the placentas of the two species. The cat's placenta is of the endotheliochorial type, in which four layers of tissue are interposed between maternal and fetal circulations, namely, endothelium of maternal blood vessels, chorionic epithelium, chorionic connective tissue, and endothelium of fetal blood vessels. The guinea pig's placenta, however, is of the hemochorial type, having only chorionic epithelium and fetal endothelium. Through this slighter barrier, transfer is more rapid.

As in the guinea pig, so also in the cat the curve of relative growth of the fetus is parallel with that describing the relative rate of transfer of radioactive sodium to a unit weight of the fetus at different periods of pregnancy.

THE REPRODUCTIVE ORGANS AND THEIR HORMONES

ACCESSORY CORPORA LUTEA

In his contribution to a volume in honor of Professor Ludwig Fraenkel, now living in Montevideo, Dr. Corner calls attention to the existence in ovaries of the rhesus monkey of a peculiar kind of corpus. This is an accessory corpus luteum, found in the ovary simultaneously with a standard corpus luteum. It is smaller than the corpus

luteum of which it is a satellite, but shows the same structure and arrangement, and runs through the same life cycle. It contains the remains of an ovum, indicating that it has formed from an unruptured follicle. Such accessory corpora lutea are obviously produced by the luteinization of a small follicle at the same time with the formation of a typical corpus luteum from a large follicle. We must suppose that these

accessory corpora are able to produce progesterone; this might occasionally be a significant addition to the total output of the hormone, for in one case the accessory corpus was large enough to represent about 8 per cent of the total mass of corpus luteum tissue.

RATE OF SECRETION OF ESTROGENIC HORMONE

In spite of all the work that has been done on the endocrine glands, we have very little information as to how much of any given hormone is available in the body, or the rate at which it is produced. The information on which such a calculation must be based is not available for most of the glands. In 1937 Dr. Corner published a calculation of this sort with respect to the rate of secretion of the hormone of the corpus luteum, progesterone. It has turned out that this calculation gave a good approximation to the truth.

This year the same sort of calculation has been attempted with respect to the output of the estrogenic hormone by the ovaries of the rhesus monkey. The method of estimation is to determine by experiment the amount of estrogenic hormone which must be given to castrated female monkeys to reproduce known functional effects of the ovaries. For example, one can find out how much estrogenic hormone must be given to prevent the uterine bleeding which follows sudden removal of the ovaries. Another way of getting at the matter is to find out how much estrogenic hormone is needed to prevent the red "sex skin" of the rump and thighs from becoming pale after castration. By these and other methods of calculation we arrive at the result that the probable daily output of estrogen by the young adult rhesus monkey is equivalent to about 200 international units (20 gamma) of ketohydroxyestrin. By multiplying this by a factor of 15, for the

proportionally greater weight of a human female, we arrive at a tentative estimate of 3000 international units (300 gamma). This is not far from an estimate, based on clinical trials by Dr. Willard M. Allen, of 4200 international units daily.

In the case of the corpus luteum it was possible to calculate with some plausibility the number of molecules of the hormone made by one cell in a given time—information of a sort that will ultimately be useful to the biological chemist; but at present we cannot define or measure the source of the estrogenic hormone with sufficient accuracy to carry the calculation down to actual units of tissue.

EFFECTS OF ESTROGEN IN CONTINUOUS HIGH DOSAGE

Drs. Carl G. Hartman, Charles F. Geschickter, and Harold Speert have made a preliminary report on their experiment in which twenty young female rhesus monkeys received enormous, long-continued doses of estrogens, ranging from 30,000 to 50,000 international units weekly, given in oil by subcutaneous injection. In addition, each received one to four 3-mg. pellets weekly, implanted under the skin to secure the advantage of slow absorption (see below). Such heroic treatment was continued in some cases more than 27 months. As a result, bodily growth stopped, and some milk teeth failed to be shed. The hypophysis was only half normal size at autopsy. The mammary apparatus showed orderly growth including complete lobular development; the genital tract remained infantile in size, but the mucosa was modified in certain details which will be described in full later. In only one case was the classic picture of endometrial hyperplasia attained. In general, the effects of this treatment were inhibitory, as compared with the familiar stimulative effects of smaller dosages of estrogenic hormones.

ABSORPTION OF PELLETS OF CRYSTALLINE HORMONES

In 1937 Deanesly and Parkes, of London, introduced a new method of administration of the steroid hormones, namely, the implantation under the skin of small cylindrical pellets, like pieces of lead-pencil lead, made by compressing the crystalline hormones. The absorption of hormone from these little hard masses is slow and regular, giving very satisfactory effects, and the method has already spread from the laboratory into clinical use. Detailed information as to the actual rate of absorption is badly needed. Dr. T. R. Forbes has studied this question with care, using pellets of standard diameter and standard compression, weighing 6 to 10 mg. These were implanted under the skin of adult rats, and were removed and weighed at intervals until they were about 90 per cent absorbed. During this period the rate of loss of weight of the pellets, i.e. of absorption, was practically linear. Under the conditions of the experiment, it was found that 90 per cent absorption of the pellets required the following amounts of time: desoxycorticosterone, 27 days; testosterone, 31 days; methyl testosterone, 36 days; stilbestrol, 51 days; testosterone monopropionate, 61 days; progesterone, 88 days.

ACTION OF TESTOSTERONE AND ESTRONE IN A MALE LIZARD

As part of his program of investigating the effects of the gonadal hormones on reptiles, Dr. Forbes has administered relatively large doses of testosterone and estrone to adult sexually mature males of the Texas lizard *Sceloporus spinosus floridanus*. The hormones were given as pellets implanted in the peritoneal cavity, and left in place for 6½ weeks, after which the lizards were killed. The experiments were carried out in February and March; the

animals were killed, therefore, at the time when they are normally in full breeding season. An ample series of controls gave opportunity to study the normal anatomy and histology of the male reproductive system of this species.

The description of the normal anatomy will be of value to special students; an interesting feature is a full account of the remarkably specialized and hypertrophied tubules of the kidney, already known to occur in adult males of several snakes and lizards during the breeding season. In *Sceloporus* Dr. Forbes identifies these structures as collecting tubules, not segments of the renal tubule proper or nephron, as previous workers have considered them in other species.

The two hormones produced definite and largely contrasting effects. Testosterone caused moderate reduction in the volume of the testis, stimulation of spermatogenesis, hypertrophy of the Müllerian duct segments with hyperplasia of their mucosa, marked hypertrophy of the epididymes and vasa deferentia, and apparent stimulation of the femoral glands. Estrone caused marked reduction in volume of the testis and virtual cessation of spermatogenesis, and atrophy of the seminiferous and epididymal tubules and of the cloacal and femoral glands. It produced, however, conspicuous hypertrophy of the Müllerian duct segments with hyperplasia of their mucosa. The cells of the specialized renal collecting tubules were reduced in height and gave evidence of reduced secretory activity. There was a definite stratification and also some cornification of the urodeal and proctodeal mucosa of the cloaca, a matter of considerable theoretical interest because of its similarity to the action of estrogenic hormones on the vagina in mammals; it is especially noteworthy that it occurs in the male lizard as well as in

the female, in which sex it has already been demonstrated by Danchakoff.

ACTION OF DESOXYCORTICOSTERONE IN THE RHESUS MONKEY

It is characteristic of scientific investigation that in a period of advancing knowledge our conceptions of a given field are clarified, made diagrammatic, and even oversimplified; then comes a phase of new exploration, in which very often the facts observed do not exactly fit the diagram so ardently wrought out, or, at the very least, force us to elaborate our theoretical schemes to allow for a more complex set of facts than had been foreseen. This is at present the case in the field of the steroid hormones. Since the isolation of the ovarian hormone (estrogen), the corpus luteum hormone (progesterone), testosterone and androsterone of the male, and the hormones of the adrenal cortex, it turns out that not only are these substances very closely related chemically, but they actually overlap in their biological effects. A striking example is brought out by the studies of Dr. Harold Speert on the action of desoxycorticosterone in the female monkey. This hormone, one of the series isolated from the adrenal cortex, is very closely related to progesterone and in fact can be derived from it theoretically by the substitution of a hydroxyl group at carbon 21. In rabbits it has a typical progesterone-like action; it maintains pregnancy in castrated mice and rabbits, and it inhibits the vaginal estrous changes in mice and rats. Conversely, progesterone exhibits an activity characteristic of desoxycorticosterone, namely, maintenance of life of adrenalectomized animals. On the other hand, in some respects this component behaves like an estrogenic hormone. Dr. Speert finds that in doses of 10 mg. per day, its action on the castrated monkey is chiefly like that of

an estrogen. It increases vaginal desquamation, re-establishes sex-skin coloration, and causes growth of lobules and alveoli of the mammary gland. Obviously the effects of the various active steroid substances will have to be studied and recorded individually, and the species of animals used will have to be taken into account.

HYPERPLASTIC NODULES IN THE MAMMARY GLAND

While studying a large series of mammary glands of castrated female monkeys, Dr. Speert has observed the regular occurrence, beginning about one month after castration, of circumscribed nodules of hyperplastic epithelial tissue arising from the acini of the glands. The cells of these nodules contain numerous mitotic figures and show the usual cytological signs of secretory activity. Some of the nodules are extremely vascular. Less regularly, areas of cystic dilatation of the acini also occur. These changes may be prevented by the administration of estrogenic or androgenic hormones. They do not occur in animals castrated during pregnancy, probably because of the high level of ovarian hormones. Similar nodules have been seen in certain strains of mice during postlactational involution, but this is the first report of their association with castration.

MATING BEHAVIOR

In continuation of her studies on the relation of the ovarian and pituitary hormones to mating behavior, Dr. Josephine Ball reports that in three completely hypophysectomized female rats, sexual excitability was induced by injections of estradiol benzoate. This indicates that the estrogenic hormone acts, in this respect, directly, and not through the hypophysis as had been previously suggested.

INADEQUACY OF A SINGLE MATING FOR IMPLANTATION

After the mammalian ova are discharged from the ovary and started down the Fallopian tube, and fertilized, they are still not relieved of dependence on the maternal ovaries. Dr. Ball describes certain experiments which illustrate this fact strikingly. It must be explained that in the rat and mouse, in which the reproductive cycles are very short (almost 5 days), there is a special mechanism which prevents the female from having two successive lots of eggs fertilized in two successive cycles. If this should happen, the second batch of embryos would arrive in the uterus before the first batch was implanted. What is more, the appearance of a new crop of follicles in the ovaries would prevent the corpora lutea corresponding to the first lot of eggs from performing their necessary functions. What actually happens is that the act of copulation reacts on the ovaries by way of a stimulus from the vagina. This inhibits the next ovulation, postpones the recurrence of the cycle, and leaves the corpora lutea of the ovary and the embryo free to get implantation under way without interference.

The seminal fluid of the male rat be-

comes coagulated in the vagina, forming a plug. It seems to be the presence of these plugs which causes the special stimulus referred to above. When the animals are left in the mating cages over night without interference, three plugs are usually formed, indicating three copulations in the mating period. Dr. Ball finds that if only a single ("one-plug") mating is permitted, about one-third of the matings fail to result in pregnancy. The eggs are fertilized, but do not go on to normal implantation. In such cases the next cycle comes on in 5 days. If three plugs are formed, the corpora lutea are always functional, and the next cycle is duly postponed, facilitating implantation of the embryos.

What has been said is true of the hooded rats in Dr. Ball's colony. In a small lot of albino rats, one-plug mating was much more effective. The conclusion is that in some rats a single insemination is insufficient to insure inception of the chain of events necessary to prepare the uterus for implantation, and that this process is quite independent of the fertilization and early growth of eggs. Failure of pregnancy may, of course, be due to failure of the eggs to be fertilized or to develop. It may also be due to failure of the endocrine mechanisms of early pregnancy.

ENDOCRINE ORGANS

BLOOD VESSELS OF THE RABBIT'S HYPOPHYSIS

In recent years a great deal has been learned about the function of the hypophysis (pituitary gland) and the adjacent hypothalamic part of the brain, by experiments in which the connections between the gland and the hypothalamus, in particular the pituitary stalk, have been purposely cut or otherwise damaged. In such experiments the aim is to interrupt nervous pathways and thus to work out the connec-

tions of the nervous system with the endocrine tissue. The question has been raised whether the experimental operations may not also have damaged the blood supply of the gland. If this were true, it would of course deprive us of the assurance that the effects obtained were valid evidence for deductions about nervous connections. Dr. C. McC. Brooks, of the Johns Hopkins Department of Physiology, and Dr. I. Gersh, of the Department of Anatomy, have attacked this problem by injecting ink into

the blood vessels after cutting various parts of the blood supply to the gland. They find that there is a free anastomosis between the capillary beds of different regions of the anterior lobe of the hypophysis. When only a part of the arterial supply is left intact, the capillaries of the whole lobe are still readily perfused with ink. In particular, complete section of the stalk does not impair the completeness of the injection. Though it is realized that injection with a colored fluid, in an acute experiment, is not a completely certain way to learn how well the blood vessels have been functioning, still the results indicate strongly that abnormalities of function caused by cutting the stalk of the hypophysis cannot be due to disturbances of blood circulation. It is highly probable therefore that they are caused by interruption of nerve pathways.

INNERVATION OF THE HYPOPHYSIS OF RABBIT AND RAT

There is evidence that in some mammals certain functions of the hypophysis (both neural and anterior lobes) are under direct nervous control. For this reason Dr. Brooks and Dr. Gersh have studied the nerve supply of the hypophysis in rats and rabbits, using the well known pyridine-silver method of selectively staining the nerve fibers. They examined not only normal animals, but also those in which the stalk of the gland had been cut or the hypothalamus injured. To ascertain possible connections with the cervical sympathetic nerves, the superior cervical ganglia were removed in some of the animals.

It was found that nerve fibers of the neurohypophysis (posterior lobe) originate in the hypothalamus. Most of these end in the neural lobe, but many continue into the pars intermedia and the anterior lobe. In the rabbit, and possibly also in the rat, these fibers in the adenohypophysis are supplemented by a smaller number arising

from the carotid plexus, which enter the anterior lobe along capsular arteries. In the rat, nerve fibers were seen to terminate in what have been interpreted as pericellular nerve nets around gland cells of the infundibular process and the anterior lobe.

THE HYPOPHYSIS IN EXPERIMENTAL DIABETES INSIPIDUS

In Year Book No. 38 reference was made to Dr. Gersh's demonstration of the general occurrence of glandular parenchymatous cells in the posterior or neural lobe of the hypophysis. Dr. Gersh brought forward much evidence to show that these cells probably secrete the antidiuretic substance characteristically found in the neural lobe.

They must therefore take part in the normal control of water excretion of the animal body. It is well known that operations causing damage to the pituitary stalk or the adjacent part of the brain (hypothalamus) cause a diseased condition (diabetes insipidus) in which the excretion of water through the kidneys is greatly increased. Dr. Gersh and Dr. Brooks now report on a series of experiments on rats in which they variously (1) removed the hypophysis or (2) produced lesions in the stalk or the hypothalamic region. The resulting physiological effects, involving diabetes insipidus or not, according to the lesion, were then correlated with the amount and condition of the glandular parenchymatous cells as found at autopsy, in the posterior lobe or in the stalk of the hypophysectomized animals. In those animals which developed diabetes insipidus the lesions had destroyed the greater part of the nerve tracts leading from the hypothalamus to the hypophysis. This causes denervation of the parenchymatous cells and results in their atrophy.

These observations lead to a theory which may be stated in the authors' words: "Briefly stated, the theory which seems to explain best the observations on experi-

mental diabetes insipidus in the rat is the following. The parenchymatous gland cells of the neurohypophysis are released from nervous control when the nerve fibers which innervate them are destroyed. In this state they atrophy. As part of the picture of paralytic secretion the less differentiated cells also denervated may then hypertrophy and subsequently atrophy through exhaustion. When the number of inactive or atrophic cells is large there is an attempt at compensatory hypertrophy. If this is successful and the remaining cells can secrete enough antidiuretic substance, the animal will show only the temporary phase of diabetes insipidus. If the hypertrophic cells are too few in number or the hypertrophy is not marked enough and the antidiuretic principle is secreted below the physiological level, the animal will suffer from a persistent, mild excess in urine output and water intake. If the differentiated cells are too few in number and the hypertrophic cells secrete to exhaustion permanent diabetes will ensue. The initial state of water imbalance in 'complete' hypophysectomy is the result of removing a major source of antidiuretic substance. Water balance will be restored when this deficiency is compensated for by cellular hypertrophy. Later when removal of the anterior lobe has produced an endocrine imbalance in the body this cellular reaction may become unnecessary and the parenchymatous cells may revert to their normal physiological state and appearance. The theory as proposed agrees with and extends the main tenets of the neuro-hormonal theory of the causation of diabetes insipidus sponsored by the Ranson school."

PROTEIN AND IODINE IN THE THYROID GLAND

The studies on the protein and iodine in the thyroid gland mentioned in Year

Book No. 39 have now been published in full. They were made by Dr. Gersh in collaboration with Dr. T. Caspersson, of Stockholm, during Dr. Gersh's stay in the latter's laboratory. Thin sections of the thyroid, prepared by the freezing-drying method, were studied under the ultraviolet microscope. By the use of Caspersson's methods it was possible to measure the absorption of ultraviolet light by areas as small as 0.5 square micron, and thus to determine quantitatively the concentration of total protein in the colloid, and of thyroxin + diiodotyrosine in both colloid and cells. About 100 individual follicles were studied. It was found in the first place that the colloid in any one follicle is homogeneous so far as absorption of ultraviolet is concerned. In the colloid of different follicles, the concentration of protein and organic iodine varies greatly. In animals treated with potassium iodide this variability was reduced; the average concentration of protein fell below normal, while that of organic iodine was not significantly altered. When the gland had been stimulated mildly with anterior pituitary extract, the variability was increased; the concentration of total protein tended to fall while that of organic iodine was relatively unaffected. On the other hand, strong stimulation with pituitary extract led to great reduction of the organic iodine. The authors set up from these facts a simple hypothesis of thyroid secretion, namely, that there is a constant secretion of "colloid" (i.e., of iodized and uniodized protein). The relative composition of iodized protein differs from time to time, under the influence of at least two factors, of which one is the level of iodine in the blood and another the physiological state of the gland cells. Newly formed colloid as it is produced becomes intimately mixed with that previously formed. The mixed colloid is then reabsorbed.

The fact that after very strong stimulation by pituitary extracts the protein in the colloid may reach normal levels, while the organic iodine falls below a recognizable level, suggests, when taken in connection with this hypothesis, that in a state of extreme activity the thyroid gland cells secrete organic iodine directly into the blood stream. This confirms a concept expressed some years ago by Professor Bensley, of Chicago.

BEGINNING OF CHEMICAL FUNCTION OF THE THYROID GLAND

Mr. R. M. Rankin, Henry Strong Denison Scholar in the Johns Hopkins Medical School, 1940-1941, has studied (at Dr. Flexner's suggestion) the development of function in the thyroid gland. Since thyroxin, or a protein containing thyroxin, is the active principle of the thyroid, the demonstration of this substance in the gland may be considered a test of its function. Mr. Rankin also determined the amounts of total iodine, diiodotyrosine, and inorganic iodine in the gland. The material was obtained from pig fetuses; since the fetal glands are very small it was necessary to use more than 2000 individual fetuses, and the results therefore represent averages rather than individual values. It

required, for example, more than 100 glands to yield a single determination for fetuses of crown-rump length less than 6 cm.

Iodine was first detected in fetal pigs of 7 to 8 cm. crown-rump length, about 46 to 50 days old. At this time all the iodine was in the water-soluble (inorganic) form. Thyroxin appears at 8 to 9 cm. crown-rump length, 52 days. At this time the only marked histological change in the gland is a great increase in vascularity. By 60 days small definitive follicles are visible in sections. Thereafter, as the amount of organic compounds becomes considerable, the acini enlarge, colloid appears, and the definitive structure of the thyroid becomes apparent.

PRESENT STATUS OF HISTOCHEMISTRY

The rapid development of the application of chemistry, physical chemistry, and physics to the determination of cell structure, and the certainty that embryology is going to make use of these methods—indeed is already doing so—gives especial interest from our standpoint to a review of recent developments in histochemistry prepared by Dr. Gersh for *Physiological Reviews*. What he has to say both of the possibilities and of the difficulties is of great interest to embryologists.

TISSUE CULTURE AND TUMOR STUDIES

CHARACTERISTICS OF MALIGNANT CELLS

As participants in one of the Bicentennial Conferences of the University of Pennsylvania, Dr. Warren H. Lewis and Dr. Margaret R. Lewis have reviewed and brought up to date the question of the morphological and functional characteristics of the cells of malignant tumors. There are two chief views as to the state of the malignant cells, i.e., cells whose growth and multiplication is not under the normal control of the

body. It may be that the growth and multiplication is kept in the uncontrolled state by the action of some agent or virus; or it may be that the cells of the malignant strain have been permanently modified by some carcinogenic agent into a new type, or mutant, for which there is no control mechanism. The studies of these investigators have made them lean toward this latter view. Although they find no known single cytological character which serves to

distinguish all malignant fibroblasts from normal ones, yet there are a few outstanding characters which usually serve to distinguish them. It is usual, for example, for sarcoma cells to average larger, and to have optically denser cytoplasm, more mitochondria, larger nuclei, a thicker nuclear membrane, more nucleolar material, and a slowing of some of the stages of cell division. Much of the evidence was ably reviewed by Dr. Warren H. Lewis in his presidential address before the American Association of Anatomists in 1935 (referred to in Year Book No. 34); the present résumé is based also on more recent evidence. For example, among the spindle-cell sarcomas produced by dibenzanthracene there is a whole series of tumors each of which seems to have its own particular type of fibroblast. In any given tumor there is a fairly high degree of uniformity of cell type. This suggests that each of these tumors came from a single cell type that was once for all caused to mutate to malignancy by the carcinogenic agent.

BEHAVIOR OF DOROTHY REED CELLS IN TISSUE CULTURES

In last year's report (Year Book No. 39) mention was made of a new way of identifying the cells of the blood-forming organs, introduced by Dr. Margaret R. Lewis, namely, by studying their mode of locomotion and their characteristics of form while moving, in motion pictures of the living cells in tissue culture. Dr. M. R. Lewis has since applied the method to the so-called Dorothy Reed cells, characteristic of the lesions of Hodgkin's disease. She finds that the small Dorothy Reed cells migrate freely with a writhing motion, some of them being identical in size, shape, and type of locomotion with the myeloblasts. The large Dorothy Reed cells are sluggish and in size, shape, and type of movement

resemble the megalocaryocytes except that their nuclei are not lobed, are larger, and have heavier nuclear membranes. They are not phagocytic and do not move like normal macrophages, epithelioid cells, or Langhans' giant cells. Compared with cells from cancerous lesions, these cells resemble malignant myeloblasts rather than malignant lymphoblasts and monocytes. In short, the Dorothy Reed cells appear to belong to the myeloid rather than to the lymphocytic or monocytic series.

These studies were aided by a grant from the International Cancer Research Fund.

IMMUNITY IN RELATION TO TUMORS INDUCED BY DIBENZANTHRAHCENE

Dr. M. R. Lewis reported last year (Year Book No. 39) having produced in mice of pure inbred strains, by use of the tumorigenic agent dibenzanthracene, six sarcomatous tumors. These all looked alike under the microscope, and grew alike in mice of their own strain (i.e., that in which they originated), but when implanted in mice of alien strains they grew only temporarily and then regressed. Mice in which alien tumors had grown were thereafter immune to tumors of the same strain but not those of other strains. During the year Dr. Lewis has used this exceptionally suitable material in a study of the immunity relations of the tumors. Experiments were planned to ascertain, by means of cross implantations of the six tumors in four well known pure inbred strains of mice, (1) the time during the growth of a tumor when immunity develops, (2) whether the development of tumor immunity is dependent on the survival and growth of tumor cells in the host, and (3) whether it is possible to bring about in mice of purebred strains an immunity against the growth of tumors that originated in the strain of the host as well as those that originated in other strains.

The program of experiments was necessarily too intricate to be reported in detail here. It will suffice to say that by means of carefully planned combinations and permutations of tumors and strains it was found that the immunity is brought about by the growth of living tumor cells in the host for 4 days or longer, but could not be produced by the injection of cell-free tumor proteins, inactivated tumor cells, blood and tissue from immune animals, blood from tumor-bearing animals, or skin from mouse embryos. It was possible to render the

purebred mice immune to the growth of tumors that originated in mice of the other three strains, but, except in a few instances, not to the growth of tumors that originated in mice of the host's own strain. It is clear that previous studies on immunity to transplantable tumors, made with animals not of known genetic constitution, must be reconsidered in the light of these results with pure strains, and the introduction of genetic control into studies on immunity to tumors offers prospects of a further advance in our knowledge of the subject.

MORPHOLOGICAL STUDIES

PLACE OF THE GIBBON AMONG THE PRIMATES

Dr. A. H. Schultz, whose studies on the morphology of primates, begun in our laboratory, have been carried on for some years in the Johns Hopkins Department of Anatomy but in intimate association with us, has contributed a very informative introductory chapter to Professor C. R. Carpenter's recent monograph on the behavior and social relations of the gibbon (*Hylobates lar*). The gibbon, as Dr. Schultz points out, belongs to the group of so-called higher primates, which includes also man and the great apes. Gibbons are especially adapted to arboreal life, and can move through the trees with astonishing speed by swinging on one arm and then the other. For this activity their arms are considerably specialized. From a review of the details of their general structure, Schultz makes it clear that the gibbons represent a branch of the primate family which separated from the general line of the ape-monkey stock after the lower primates (monkeys) separated off, about the same time as man, before the three great apes became differentiated. Thus, of the five main types of higher primate, man and gib-

bon are relatively removed from the others and from each other, and orang, gorilla, and chimpanzee are a more closely associated group.

CHEVRON BONES IN MAN

Dr. Schultz has reported an example of a chevron bone in man, the fifth such case on record. Chevron bones are bony arches on the ventral side of the caudal vertebrae, normally present in animals which have well developed tails. They form a canal for the blood vessels of the tail. When present in man the chevron bone is at the level of the first coccygeal vertebra. R. G. Harrison (1901) and C. R. Bardeen (1905) first pointed out the existence of rudimentary hemal arches in the coccygeal region of the human embryo. The embryos studied by these investigators were in the Mall collection of embryos, which formed the nucleus of the Carnegie Collection, and it is curiously appropriate that a case of the very rare persistence of the hemal arch in the adult human should have been found by an investigator (Dr. Schultz) so closely associated with the collection.

PHYLOGENY OF THE HUMAN FOREARM EXTENSORS

In an extensive article Dr. William L. Straus, Jr., of the Johns Hopkins Department of Anatomy, has reviewed the question of the phylogeny of the human forearm extensor muscles. His account is based on the dissection of a large number of primates and other mammals, and on thorough collation of the literature on infra-primate vertebrates. The resultant discussion, necessarily too detailed to permit summarization here, is summed up in an instructive table showing the homologies of these muscles in representative tetrapods. Two general conclusions of great interest are mentioned. One is that although the primates, as an order, show but few peculiarities when compared with other mammals, yet there are a good many detailed characters involving the forearm flexor muscles which are found only in the higher primates, i.e., gibbon, orang, chimpanzee, gorilla, and man. The distribution of these characters within that group suggests a community of origin for man and the anthropoid apes. The study of the muscles therefore confirms the evidence of the skeleton. Dr. Straus feels that the special characteristics of the human arm muscles, as distinguished from those of the anthropoid apes, indicate that man did not pass through an ancestral stage in which progression was by the method of brachiation (i.e., swinging from arm to arm through the trees), as has been conjectured by some comparative anatomists in recent years. The other general point of special interest has to do with the distribution of nerves to the forearm flexors, in relation to the well known Fürbringer hypothesis, which states that in the evolution of the muscles, the nerve pathways follow, so to speak, the muscles as they subdivide, shift,

and migrate. The homologies of muscles could therefore be determined by means of their innervation if the hypothesis were infallible. Dr. Straus has found, however, so much alteration, simplification, and transference of pathways in the pattern of nerve supply that he is forced to consider the Fürbringer hypothesis not absolutely valid.

THE POSTURE OF THE HAND IN LOCOMOTION

Chimpanzees, orang-utans, and gorillas, when they walk in quadrupedal fashion, put their hands to the ground in such a way that they walk on their knuckles. Monkeys, on the other hand, place their palms flat on the ground. Those human infants who pass through a stage in which they run on all fours, as described by Professor Hrdlička of the U. S. National Museum in an interesting book some years ago, put the hand on the ground like the monkeys, not like the anthropoid apes. Dr. Straus points out, on the basis of dissections as well as study of living chimpanzees, that the anthropoids actually cannot extend their fingers sufficiently to put the palms on the ground when the wrist is dorsiflexed, because the flexor muscles of the fingers are too short. The anatomical arrangements (relating to muscle and joints) which thus force them to walk on their knuckles are, on the contrary, of great importance in hanging by the hands and therefore in progression by brachiation. The gibbons, which brachiate extremely well, do so by means of still another set of modifications not involving shortening of the digital flexors. The upper extremity of man is fundamentally closer to that of the catarrhine monkeys than to those of his closer relatives, the higher apes.

THE NERVOUS SYSTEM

STIMULATION OF THE MOTOR AREA OF THE BRAIN IN THE CHIMPANZEE

The termination of Dr. Schultz's observations on the growth of three chimpanzees which had been kept for several years in the Johns Hopkins Department of Anatomy provided Dr. Marion Hines with a fortunate opportunity to study the cortex of the brain by direct electrical stimulation. Since the classic work of Sherrington and his associates was done, an improved method of stimulation has been introduced, i.e., the accurately controlled sine-wave current. Meanwhile also there has been a great increase in our knowledge of the cytoarchitectonics of the cortex, that is to say, the detailed and specialized arrangement of nerve cells in the various functional regions. These developments make it valuable to restudy the localization in the motor cortex.

Although the new "map" of the precentral gyrus obtained by means of these experiments is in general similar to previous results, it is richer in detail and more precise. Technical questions of relative sensitivity of different areas, of the optimum rate of stimulation, and of the exact types and combinations of movements obtained have been worked out with results that will be of great interest to neurologists.

INNERVATION OF THE PANNICULUS CARNOSUS IN THE ARMADILLO

It is always a matter of interest when there is a suspicion that a given muscle is supplied from two or more widely different sources. Such cases require investigation for general embryological reasons, and particularly because of the Fürbringer hypothesis, mentioned above, which postulates that the relation between a muscle and its nerve supply is fixed and persists even

though the muscle shifts its position or is otherwise modified. Dr. S. S. Miles, working with Mr. Brazier Howell, brings forward a case of possible multiple innervation, namely, the panniculus carnosus, the superficial muscle layer on the shoulder and flank of the armadillo, immediately under the shell. This muscle layer is, of course, equivalent to similar layers under the skin of other animals. In the armadillo it is reached and entered by a complex network of nerve fibers from the anterior branches—intercostal nerves 2 to 8, branches of the anterior thoracic (pectoral) nerve, and lateral branches of the intercostals. Dr. Miles investigated the situation by direct electrical stimulation of the nerves as far as possible, and arrives at the conclusion that no motor innervation of the panniculus carnosus can be demonstrated except the anterior thoracic (pectoral) nerve. The other nerve fibers mentioned are probably all of sensory nature; most of them pass through the muscle to the overlying shell. The innervation of this muscle is therefore not atypical.

EARLY CONTRACTIONS OF FETAL MUSCLE

Dr. William L. Straus, Jr., working with Dr. Graham Weddell at University College, London, has studied the earliest visible contractions of the fore-limb muscles in rat fetuses. These are found on the 16th day of gestation. At this time the rat fetuses are, of course, very small, and it was not possible to apply the usual instrumental physiological methods of study, but only to observe the contractions ocularly. The responses of the fetal muscle to electrical stimuli are characterized by relatively long duration of the effect, a high threshold of excitability, and relatively long delay of visible response. These features,

which are quite different from those of normal adult skeletal muscle, agree with those observed by previous workers, and have generally been taken to reflect the intrinsic physiological properties of muscle in its earlier stages of differentiation. Straus and Weddell point out, however, that when as in the study of fetuses the action of muscle has to be studied by watching its effect on the position of the limb, we must remember that other tissues are involved. Fascias, though developing, are still rudimentary in the 16-day rat; tendons are not yet developed, the articulations are in the earliest stages of formation, and there are as yet no joint cavities. The consistency of the tissues and the rigidity of the lever system involved are very different from the

adult condition. The long latent period of muscular contraction, the long chronaxie, and the slowness of contraction may all be false appearances.

In some of the experiments it was possible to elicit contraction of muscles by stimuli applied at a distance, and almost certainly transmitted by nerves. At this time primitive nerve terminations are present within the muscles of the fore limb, although definitive nerve endings are not detectable. We cannot ignore the possible participation of nerves even when the muscular contraction is in response to direct stimulation. The investigators find no proof that there is a purely "myogenic" stage of activity of striated muscle in mammals.

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DEPARTMENT OF GENETICS

Cold Spring Harbor, Long Island, New York

A. F. BLAKESLEE, *Director*

The arrangement this past summer whereby the symposium of the Long Island Biological Association was devoted to a genetic subject gave the Department an opportunity to offer facilities of land for experimental plants to those plant breeders who were in residence in Cold Spring Harbor during this period. The following investigators were thus guests of the Department and grew on Departmental grounds the plants listed in parentheses: Dr. M. M. Rhoades, of Columbia University (maize); Dr. and Mrs. B. R. Nebel, of Geneva, New York, Agricultural Experiment Station (*Tradescantia*, snapdragons, and marigolds); Dr. Barbara McClintock, of the University of Missouri (maize); Dr. Harriet B. Creighton, of Wellesley College (maize); Dr. Edgar Anderson, of Missouri Botanic Garden (maize); Dr. Norman Giles, of Yale University (*Tradescantia*); Professor W. J. Bonisteel, of Fordham University (*Digitalis*). It has been of distinct advantage to the Department to have the association of such outstanding geneticists as were in Cold Spring Harbor during the summer.

A detailed report of the scientific work of the different research groups of the Department for the year ending September 1, 1941, is given in succeeding pages. These reports will be briefly summarized.

The group studying the gene have devoted considerable attention to the relation of genes to breaks in the chromosomes induced by radiation. Analysis of deficiencies in the Notch locus made by Drs. Demerec and Fano indicates that deficiencies up to about 15 salivary-gland chromosome bands in length may be caused by

one-event process, whereas larger deficiencies are induced by two events. Thus a single-event process may have a radius of action of about 600 Å. An analysis of the data regarding breaks in chromosomes indicates that in about 10 per cent of cases a break affects the locus in its proximity. From a study of dominant lethals Dr. Fano is led to conclude that they cannot be entirely explained by single breaks in chromosomes, but that they frequently involve some as yet unobserved type of chromosomal rearrangement. Cooperative experiments with monochromatic ultraviolet radiation undertaken by Drs. Demerec and Hollaender show that a difference exists between the effects of the different wave lengths. Since the *Drosophila* males when subjected to treatment are easily injured by shorter wave lengths, these investigators have found it necessary with higher dosages to use the longer wave lengths. Difficulties are encountered in the use of ultraviolet radiations due to difficulties in penetrating the tissues surrounding the germ cells which are treated. When these difficulties are overcome the rate of gene mutations may be very high. Added evidence has been found to show that ultraviolet differs from X rays and radium in being ineffective in inducing breaks in chromosomes although it is effective in inducing gene changes. Drs. Kaufmann and Demerec have found that the amount of sperm transferred by a male of *Drosophila* in a single copulation was sufficient for the fertilization of a high percentage of eggs only during the first few days of egg-laying. When more than a single male had mated with a given female it was

found that differences in percentages of the different types of offspring obtained can be attributed to differential viability of embryos and larvae and not to differential viability of sperms leading to selective fertilization. Dr. Brehme found that a number of eye-color mutants in *Drosophila* affect the color of the larval mouth parts and spiracle sheaths and can be used as larval characters as well.

In the group which devotes especial attention to chromosomes, Miss Satina has found additional evidence that there are three distinct germ layers in *Datura* by means of periclinal chimeras, in which the layers are labeled by differences in chromosome number. By periclinal chimeras she has shown that the stamen is a reduced axis, and not homologous with a leaf as is the classic belief. In a study of chemical regulation of embryo development, Drs. van Overbeek and Conklin have developed a technique whereby they are able to take out proembryos less than 0.2 mm. in length and induce them to grow *in vitro* on artificial media. Others have grown nearly matured embryos *in vitro*, but no one before has succeeded with such small embryonic growths. A factor contributing to their success was the use of coconut milk, which supplied certain necessary substances. The technique bids fair to be of use in securing hybrid plants which normally abort at an early stage of embryonic growth. If the attempts being made to grow unfertilized egg cells *in vitro* are successful, a method of inducing parthenogenesis will have been secured. Miss Satina and Mrs. Sansome have shown that very few viable seeds are secured from the cross between a tetraploid and a diploid because most of the $3n$ embryos abort after about 6 days. Since both the $4n$ and $2n$ parents of the cross were from the same inbred line, individual gene differences seem to be eliminated as a cause of the early abor-

tion. The difficulty in securing a cross between diploids and tetraploids is an isolating mechanism which tends to keep newly arisen tetraploids separate from populations of diploids from which they may have originated. Dr. Bergner has made a summary of her extensive study of the chromosome end arrangements in types from nature of six species of *Datura*. Most of the chromosomes are found to have suffered interchange of segments when all the species of *Datura* are considered. The number of interchanges which have taken place in any given species, however, is seen to be relatively small. A recessive gene type has been found in *Datura* which closely resembles in its external appearance the *quercina* virus disease of this species. The morphological similarities suggest a similarity in nature of the virus and the gene or in their method of bringing about changes in the host plant affected. Dr. Warmke has found new polyploid types in *Melandrium* which are being used in furthering our understanding of the sex mechanism in this dioecious species.

There seems to be increasing agreement as to which particular hormone from the pituitary gland stimulates the different special organs of the body. There is wide disagreement, however, as to which pituitary hormones are involved in generalized metabolic processes. For this reason Dr. Riddle and Mr. Opdyke, aided by Drs. Bates and Miller, of the group interested in the endocrine glands, have made a special study of the metabolism of carbohydrate and fat. They report first on the effect of the six fractions which may be obtained from fractional precipitation of pituitary extracts with ammonium sulphate, regarding which there is considerable though somewhat conflicting material in the literature. The original solution and the five fractions derived from it all contained four of the five hormones looked for, the origi-

nal solution having the greatest potency in increasing blood sugar. The fractionation brought about a concentration of prolactin in two fractions, and these were most effective in increasing liver fat in pigeons. Dried preparations increased acetone bodies in blood of rats, but fresh solutions were more effective in pigeons and rabbits. Only the fraction freest from both thyrotrophin and prolactin failed to increase heat production in pigeons. Fractions which others have found to cause experimental diabetes (the increased production of sugar and acetone in the blood) in the dog were shown in normal pigeons to have only temporary diabetic tendencies. Pigeons will tolerate huge doses of insulin, which soon give rise to symptoms of diabetes for which in mammals insulin is used as a cure. After two or three treatments the increase of blood sugar may amount to as much as 100 per cent. After the first injection blood acetone and liver fat are increased, but within 48 hours these effects are replaced by a large increase of liver glycogen. A single injection of prolactin results in a great increase of liver glycogen, and this increase is not maintained by later injections. From these findings Riddle concludes that no single hormone of the pituitary is responsible for the increased formation of acetone, blood sugar, or liver fat. Rather he believes they show that the normal regulation of metabolism of carbohydrate and fat is more seriously deranged when two or more participating hormones are present in unusual concentration and exert their stimuli simultaneously. Valid evidence seems lacking for any unrecognized pituitary hormone with specific action on the metabolism of either carbohydrate or fat. By injecting a minute quantity of the female sex hormone into a female dove shortly before the release of an ovum from her ovary, Drs. Dunham and Riddle found that male embryos from

eggs thus treated are partly feminized. They develop left oviducts, which are normally absent in males, and the trace of ovarian tissue which male dove embryos normally carry temporarily on their left testis is both increased in amount and made to persist much later in life. It is suggested that the bisexuality shown by the trace of ovarian tissue on the left testis of males at hatching is itself the result of sex hormone passed by the mother into her maturing eggs. The present studies confirm the earlier view of Riddle that feminine characteristics shown by male doves are probably caused by excess female sex hormone which the egg receives from the mother.

The group studying mouse genetics reports the discovery of a monogenic mutation, screw tail, that promises to provide valuable material for the analysis of genic control of development in an extremely constant genotype. This group further reports that the apparent inheritance of a tendency to spontaneous leukemia can now be related partly to strictly genetic influence and partly to extrinsic influence depending on the nurse. The significance of this result has been established through the cooperation of Dr. John W. Gowen, who is carrying out statistical analyses of the interrelations among the extensive observations gathered to determine by breeding tests whether Mendelian segregation follows the outcross of a high-leukemia strain. Dr. Gowen's results indicate that genetic segregation does take place, but that the significance of the evidence depends on the strain of the nurse. The surprising feature of these results is that nurses from two strains in which leukemia has rarely been found have different effects on the appearance of leukemia. This observation led to a retabulation of the earlier data from F₁ matings between the strains used in the above outcross. Even greater differences

appeared, related to the same two strains of nurses, and the difference between reciprocal matings, reported earlier, was found to be eliminated when the strain of the nurses was held constant. The incidence of leukemia in this first hybrid generation varied from 74 to 50 to 35 per cent according to the strain of the nurses.

Dr. Steggerda in his studies in anthropology and human genetics has devoted considerable attention during the past year to characteristics of human hair in different racial groups. It has been shown that race, sex, age, and distance from the scalp are all factors in producing different widths in human hair. Steggerda has also made a careful study of the change in color of hair during a 10-year period for more than 400 children ranging in age from 6 to 18. During this age range there is a progressive darkening of the hair amounting to about one unit of the Fischer scale per year. This gives a correlation of 0.53 between

hair color and age. Another study concerns Maya agronomy. An experimental plot, kept in corn for several years, is gradually losing in productivity. In spite of careful hand weeding, tough grasses are slowly invading the area. These growths, ineradicable by any means available to the Maya, seem, in addition to the normal impoverishment of a thin soil, to have forced the Maya to employ the so-called "milpa" system, under which any given piece of land is left lying fallow for ten or more years. This system obviously demands so large an amount of territory that populations would be forced to move more often into new areas than would be the case were fertilization possible, or could the grasses and weeds be combated by plowing. The difficulties of agriculture, therefore, seem to be a possible explanation of the ancient Maya's apparent inability to remain in a given locality for more than a relatively short time.

CHROMOSOME INVESTIGATIONS

A. F. BLAKESLEE, A. G. AVERY, A. D. BERGNER, S. SATINA, H. E. WARMKE, J. T. BUCHHOLZ,
M. E. CONKLIN, E. R. SANSCHE, E. W. SINNOTT, AND J. VAN OVERBEEK

GENES IN Datura

In the last year's report a classification made by Avery was given of the genes distinguished in *Datura*, which now number approximately 500, with 77 located in particular chromosomes. The number of pollen-abortion genes which have been located has been increased so that we now have at least one pollen-abortion gene for all except two chromosomes and have two such genes for each of four chromosomes. They are of unique value in determining the position of other genes within a given chromosome through linkages, without the difficulties inherent in working with double recessives.

SIMILAR EFFECTS FROM A VIRUS AND FROM A RECESSIVE GENE

One of the recessive gene types recently secured through X-ray treatment of seeds is of especial interest since it closely resembles in appearance the *quercina* virus disease. Both the *quercina* virus and the *quercina*-like gene cause the elimination of spines from the capsule, the separation of the tubular corolla into individual petals, the extension of the stigmatic surface on the inside of the lobes and down two sides of the style, and the production of narrow, eroded leaves. Miss Satina has shown that the separation of petals in the flower by both the *quercina* disease and the *quer-*

cina gene type is brought about by the same mechanism, namely, a more rapid growth of the outer sides of the young petals, which are bent inward in the form of a letter U. The edges are thus prevented from meeting and fusing as they normally do in early stages in the bud. The *quercina* disease can be transmitted to a healthy plant by grafting, but this is not true of the *quercina*-like mutant type. It is apparent that genes and environmental factors may bring about similar end results through their effects on the developmental processes in the plant. The similarity of the effects of certain genes and viruses suggests that they alter the internal environment in similar manner. Both viruses and the determiners of heredity exist as discrete self-perpetuating particles, and both are subject to induced mutations. The similarity of their action supports the suggestion that the chief difference between the two may lie in the fact that the virus particle is free and hence capable of undergoing uncontrolled reproduction, whereas the gene is confined to a specific locus within the chromosome and its propagation is limited by the mechanism of heredity. The facts give support to the suggestion of an evolutionary relationship between viruses and genes. It should be emphasized that similarity of end results is not proof of identity of cause; but the similarity in the present case is so striking to one familiar with the expressions of the virus disease that it would seem profitable to explore the possible similarities of the two forms further. It would be of interest, for example, to test the chemical relations by means of the antigen-antibody reactions. Now that we have both the virus and the gene types under cultivation, it is hoped such further tests will be possible.

PERICLINAL CHIMERAS

In last year's report we spoke of the new insight into the manner of development and organization of the *Datura* plant gained by means of periclinal chimeras, in which the individual germ layers are labeled by having a different chromosome number from the adjacent tissues. This work has been extended by Miss Satina with the accumulation of additional evidence for our former conclusions and with new conclusions from new evidence.

In order to get some idea of the prevalence of periclinal chimeras, a random sample of 100 plants grown from seeds heavily treated with colchicine were tested for the constitution of their germ layers. Of the 100 plants, 47 appeared to be normal throughout; 11 were mixo-chimeras; in 33 plants about half the branches were normal and the other half were periclinal chimeras with one, two, or three of the germ layers having duplicated chromosome numbers. In 3 of the plants all the branches appeared to be periclinal chimeras with the germ layers affected in the same way; and in 6 plants there were several types of periclinal chimeras in the different branches. During the past year six new types of periclinal chimeras have been found, which, with those previously identified, make a total of fifteen types. The most useful for detailed studies on the development of various organs are those in which one of the three germ layers is octoploid ($8n$) and the other two normal diploid ($2n$).

Some morphologists who are not favored with an adequate method of labeling the individual germ layers have expressed some skepticism concerning our earlier conclusions regarding the germ-layer constitution of the shoot apex, especially our conclusion that the cells of the central core

are derived from the innermost (third) germ layer. It seemed desirable, therefore, to secure additional evidence regarding the matter. We are now able to report from study of over 200 periclinal chimeras. In all these cases the cells of the central core have the same chromosomal constitution as the third layer, and the evidence seems compelling that they are derived from the third layer. Our conclusion, therefore, stands that at least in *Datura*, the shoot apex has three and only three independent germ layers. The same three independent germ layers are also found in the floral apex, which shows no essential difference in structure from the shoot apex. The initial and early development of the sepal and petal is similar to that of the leaf, but that of the stamen is different and suggests that the stamen is a reduced axis. Detailed studies have been begun by the use of periclinal chimeras to determine the contribution which the different germ layers make to the development of the carpel and ovules. A study has also been started to find out the time and manner of differentiation of the three germ layers in the developing embryo.

CHEMICAL REGULATION OF EMBRYO DEVELOPMENT

Last year we reported attempts to secure haploid ($1n$) plants in *Datura* through the induction of parthenogenesis (development of the unfertilized egg cell) by means of injections of a wide range of chemical substances. The basis of our attempts was the fact that the *Datura* plant had shown itself capable of producing such $1n$ plants through some unknown but presumably chemical stimuli. Although we failed to find any method of inducing parthenogenesis, we were able to show that a number of succeeding stimuli are necessary for the full development of an embryo.

It seemed best to attack the problem the present year from a different angle, and Drs. van Overbeek and Conklin have this summer been investigating the possibility of taking out embryos at various stages of development and growing them on artificial media. Since no method of growing very young embryos *in vitro* was known, their first step was to find a medium which would support growth from the proembryo stage to maturity. An agar medium containing nutrient salts, dextrose, and nine different vitamins and growth factors was found suitable for growing *Datura* embryos with partly developed cotyledons. Younger embryos could not be grown on this medium. A unique method of growing young embryos was discovered, however, by adding to the nutrient a natural endosperm in the form of coconut milk. By this technique it has been possible to secure the growth *in vitro* of proembryos 0.15 mm. long which were taken out of the embryo sac only 10 days after pollination. With the technique developed, it is hoped to be able to remove the egg cell from the embryo sac by a microinjection apparatus and to obtain growth and development on artificial media. If this can be accomplished we shall have solved the problem of artificial parthenogenesis in *Datura*. The success of coconut milk in furnishing some accessory substance or substances which stimulates the growth *in vitro* of excised embryos suggests its applicability in other species. A method of securing growth of young embryos on artificial media might insure the success of many wide crosses hitherto impossible. Such a technique would be of great theoretical as well as practical importance.

CROSSABILITY BETWEEN $4n$ AND $2n$ DATURA

When the first tetraploid ($4n$) plant in *Datura* was discovered, in 1917, it was

labeled "new species" because of the difficulty of getting crosses between it and the normal parental type from which it had arisen. When the tetraploid was used as the male parent crosses were practically never obtained, and when the tetraploid was the female parent the number of viable seeds from the cross was extremely small. Although many hundred attempts were made to secure offspring from the cross $2n \times 4n$, only one seedling has resulted. Buchholz has shown that the primary block to this cross is the fact that the $2n$ pollen tubes from a tetraploid are almost never able to grow through the style of a diploid without bursting. The pollen tubes in the reverse cross, $4n \times 2n$, appear to function perfectly. Avery has summarized the records from the cross and finds that a total of 97 offspring have been recorded. Of these 54 were triploid ($3n$), 33 diploid ($2n$), and 10 tetraploid ($4n$). The diploids were undoubtedly all due to parthenogenesis of unreduced $2n$ egg cells, since in those cases in which the two parents were labeled by genes, the diploids were like the female parent. The tetraploids were possibly due to accidental selfing.

Miss Satina and Mrs. Sansome have been investigating the factors involved in the reduction of number of viable seeds from the cross between tetraploids and diploids. Tetraploids of *Datura stramonium* when selfed gave an average of about 88 seeds per capsule, but the $4n \times 2n$ cross gave an average of only about 3 seeds per comparable capsule. Examination of 291 ovules from an ovary 6 days after pollination showed that 70 per cent had a proembryo and endosperm, and that 18 per cent were degenerating and probably had had both a proembryo and an endosperm. Fertilization may have occurred in some of the remaining 12 per cent, which includes cases more difficult to classify. A high degree of ini-

tial fertility is thus evident. Chromosome counts of a dozen endosperm nuclei, each from a different ovule, showed the $5n$ chromosome number (60) expected following fertilization. Indications are present that union of male and female gametes takes place, although actual chromosome counts have not yet been secured in proembryos. It is probable, therefore, that the high majority of the egg cells from the cross are fertilized and start development. Shortly after the sixth day, when the proembryo is 3- to 4-celled and the endosperm 16- to 32-celled, the degeneration of both proembryo and endosperm is initiated. The degeneration is often accompanied by the enlargement and ingrowth of the somatic cells of the endothelium surrounding the embryo sac. Sometimes, however, the endothelial cells themselves break down before enlarging to any great extent. Both the diploid ($2n$) and the tetraploid ($4n$) strains used in the cross have come from the same highly inbred and homozygous line. It is not as yet clear, therefore, why the embryos which start development should degenerate in such a high proportion of the cases. It cannot be due to a difference in genic constitution of the male and female gametes which fuse to form the first cell of the proembryo—which seemed to be a plausible explanation for the failure of the cross between diploid *D. stramonium* and *D. metel*, earlier investigated by Miss Satina. It is suggestive, however, that in this latter species cross she found degeneration of embryo and endosperm frequently accompanied by an ingrowth of the endothelium which set in shortly after the sixth day following pollination. One finds qualitative differences between tetraploids and diploids, such as differences in the shape of leaves and capsules. It might be thought that the failure of the $3n$ embryo to develop in the majority of cases may be in some

way due to a difference in the ratios between the chromosome numbers of the different tissues involved in the development of the embryo.

By the use of periclinal chimeras it is possible to test an alteration of the chromosomal ratios in the opposite direction from those in the $4n \times 2n$ cross just discussed. As a result of the discovery that the tissue of the style through which the

in the reciprocal cross $4n \times 2n$. Whereas in the $4n \times 2n$ combination the ratios shown in the accompanying table are less than those of the viable combinations ($2n \times 2n$ and $4n \times 4n$), the ratios of this $2n \times 4n$ combination are seen to be greater. The ratios between chromosome numbers in the different tissues of the ovule, therefore, do not appear to offer a clue to why the $3n$ embryos develop so infrequently into viable

CHROMOSOMAL RATIOS BETWEEN TISSUES OF DIFFERENT TYPES OF OVULES IN *Datura stramonium*

(Plus (+) and minus (-) signs indicate ratios higher and lower respectively than those in the viable combinations.)

Type of ovule	$\frac{\text{Embryo}}{\text{Endosperm}}$	$\frac{\text{Embryo}}{\text{♀ tissue}}$	$\frac{\text{Endosperm}}{\text{♀ tissue}}$
Viable combinations:			
$2n \times 2n \dots$	$\frac{2n}{3n} = 0.67$	$\frac{2n}{2n} = 1.00$	$\frac{3n}{2n} = 1.50$
$4n \times 4n \dots$	$\frac{4n}{6n} = 0.67$	$\frac{4n}{4n} = 1.00$	$\frac{6n}{4n} = 1.50$
Mostly nonviable combinations:			
$4n \times 2n \dots$	$\frac{3n}{5n} = 0.60 (-)$	$\frac{3n}{4n} = 0.75 (-)$	$\frac{5n}{4n} = 1.25 (-)$
$2n \times 4n \dots$	$\frac{3n}{4n} = 0.75 (+)$	$\frac{3n}{2n} = 1.50 (+)$	$\frac{4n}{2n} = 2.00 (+)$
Parthenogenesis:			
$1n$ egg from $2n$ ♀	$\frac{1n}{2n} = 0.50 (-)$	$\frac{1n}{2n} = 0.50 (-)$	$\frac{2n}{2n} = 1.00 (-)$
$2n$ egg from $4n$ ♀	$\frac{2n}{4n} = 0.50 (-)$	$\frac{2n}{4n} = 0.50 (-)$	$\frac{4n}{4n} = 1.00 (-)$

pollen tubes grow is epidermal in nature and derived from what has been called the L-1 germ layer, it has been possible to make the equivalent of a $2n \times 4n$ cross without bursting of pollen tubes by pollinating a $4n$, $2n$, $2n$ periclinal chimera with pollen of a tetraploid. The earlier stages in ovule development from this cross are being investigated, but judging from the aborted seeds and the very small number of good seeds in the mature capsules, it is reasonable to conclude that the processes of embryo disintegration are the same as

seeds. The relative simplicity of this special problem, with differences between genes eliminated, leads to the belief that its solution may be of fundamental importance to the more general evolutionary problem of the factors involved in crossability between species. Perhaps the studies now under way on the chemical regulation of embryo development may offer an explanation. Whatever the cause may turn out to be, the fact that it is difficult to secure a cross in *Datura* between a tetraploid and a diploid from which it may

have arisen is of interest to the student of evolution in view of the origin of so many species of plants through tetraploidy. It has been pointed out that the pure-breeding types which we had synthesized with extra chromosomal material should not properly be called "new species," since we had failed to provide them with an isolating mechanism which would keep them from crossing with the normal $2n$ individuals in the population from which they were derived. We therefore doubled the chromosomes of these synthesized types and thus furnished the isolating mechanism demanded.

EFFECT OF TETRAPLOIDY ON CROSSABILITY BETWEEN SPECIES

In a series of tests of the growth of pollen tubes of each of the 10 herbaceous species of *Datura* in the styles of the other 9, Buchholz has found certain combinations in which the tubes are prevented from reaching the ovary by retardation of growth or even bursting within the style. This past year he has made a similar study of pollen-tube growth of tetraploids of the same species, which had been secured by the use of colchicine. It seemed important to discover what, if any, effect doubling chromosome number might have on crossability, since the belief has been current that tetraploidy increases crossability between species. Buchholz' work gives no support for this belief so far as the growth of the pollen tubes of Daturas is concerned. In fact, in *Datura* the tendency is rather in the opposite direction, with the result that on the average relatively fewer tubes enter the ovary in a cross between $4n$ than between $2n$ races of a given pair of species. Preliminary tests indicate that formation of viable seed from species crosses is not favored by tetraploidy. If this turns out to be generally true, it will follow that

when tetraploids arise in nature they will be no more likely to cross with tetraploids of other species than are the diploids of these species to cross inter se. We have seen from the studies of $4n \times 2n$ and reciprocal crosses discussed above that there is a distinct check to crossability between a tetraploid and a normal diploid from which it has arisen. These facts appear to have evolutionary significance.

EFFECT OF TETRAPLOIDY ON SELF-FERTILITY

The effect on fertility of doubling chromosome number differs according to the chromosomal and genic constitution of the plant affected. In general, doubling the chromosome number of a self-fertile plant such as *Datura* to form an autotetraploid results in some reduction in the number of viable seed produced. It is probable that this reduction is due in part at least to non-disjunction in meiotic divisions, leading to chromosomal deficiencies and excesses. An extreme example was furnished this past summer by cultures of *Nicotiana langsdorffii* grown in the garden. The $2n$ plants set capsules freely, but the $4n$ plants had almost no capsules at all.

One of the problems that a method of doubling chromosome number made it possible to study was the effect of tetraploidy on self-sterility. Much of the work on this problem was done by Dr. Warmke. Doubling chromosome number of a self-sterile plant in some cases may increase slightly the production of seed from selfing. Such an increase was observed in *Petunia*. Of 600 capsules from two $2n$ plants grown in a screened greenhouse, 3 per cent had seeds, whereas of about 500 capsules from two $4n$ plants, 55 per cent had seeds. In another variety of *Petunia*, 2 per cent of 327 capsules from $2n$ branches of a single plant had seeds and 27 per cent of 187 capsules from $4n$ branches of the same

plant had seeds. In neither $2n$ nor $4n$ capsules was there a full set of seed. The condition appears to be somewhat similar in *Nicotiana sanderae*. In other so-called self-sterile forms studied, the effect of tetraploidy was less evident. Thus there was no striking difference in the set of seeds from self-pollinating $2n$ and $4n$ plants of the following forms which are predominantly self-sterile: *Portulaca parana*, *Cosmos sulphureus*, *Rudbeckia hirta*. A difficulty lies in the fact that many, and perhaps most, plants which are classed as self-sterile do set a limited amount of seed from selfing. To discover an effect of tetraploidy on self-fertility in the forms just mentioned, which at best cannot be great, would require a more detailed statistical analysis than we have undertaken. In contrast with the uncertainties of the effect of tetraploidy on fertility of normally self-sterile species, doubling the chromosome number of forms such as species hybrids which are sterile on account of chromosome incompatibility brings about fertility, as is seen in the pure-breeding double diploid types we have synthesized in the genus *Nicotiana*.

EVOLUTION OF CHROMOSOMES IN NATURE

Since the beginning of the *Datura* investigations it has been our belief that the genetic findings in our detailed breeding experiments should be related to the behavior of Daturas in nature. With this idea in mind we early began the study and collection of races from nature, first of *Datura stramonium* and later of other species of the genus *Datura*. Fifteen years ago Belling in his hypothesis of segmental interchange gave the clue to the chromosomal constitution of a type from nature which differed from the highly inbred Line 1 which we had been using as a standard in our cultures. Even before this, however, we had been able to distinguish this type

by genetic methods. Belling's hypothesis, which has been amply confirmed by later study, showed that in the formation of two of the chromosomes of this type, now called Prime Type 2 (PT 2), the $1 \cdot 18$ and $2 \cdot 17$ chromosomes could be explained as having been derived by interchange of segments between the $1 \cdot 2$ and the $17 \cdot 18$ chromosomes of PT 1. Our method of testing interchanged chromosomes shows that a difference has occurred in the arrangements of their ends, but generally does not give positive evidence regarding the length of the segments involved. With the idea that the clue to the evolution of a species is to be found in the evolution of its chromosomes, an analysis has been undertaken of the chromosomes of the material in our collections. This analysis has been under the immediate supervision of Dr. Bergner. We have from time to time in past reports recorded the tests with certain individual species. It seems profitable at the present time to review the progress of our investigation of the whole genus.

We have first undertaken to make a study of the phenomenon of interchanged chromosomes in different species. These interchanges we have expressed in terms of the chromosomes of our standard line in *D. stramonium*, which we have listed in the accompanying table as Prime Type 1 (PT 1). Interchanged chromosomes are indicated by boldface type. In testing an unknown race for chromosomal constitution, we cross it with our standard PT 1. If the race in question contains a pair of interchanged chromosomes, such as the chromosomes $1 \cdot 18$ and $2 \cdot 17$ of PT 2, there will be seen at meiosis in the pollen mother cells a circle of 4 chromosomes involving the interchanged chromosomes of PT 2, in addition to 10 bivalents. By adequate tests it can be determined which chromosomes are involved in the circle. The table shows that including PT 1 there

INTERCHANGED CHROMOSOMES IN SIX SPECIES OF DATURA IN TERMS OF CHROMOSOMES OF PRIME
TYPE I OF *D. stramonium*

Datura stramonium
(680 races)

PT 1 (275 races)	PT 2 (327 races)	PT 3 (62 races)	PT 4 (83 races)	PT 7 (61 races)	PT 87 (1 race)	PT 88 (1 race)
1·2	1·18	1·2	1·2	1·2	1·2	1·2
3·4	3·4	3·4	3·21	3·4	3·12	3·4
5·6	5·6	5·6	5·6	5·6	5·6	5·6
7·8	7·8	7·8	7·8	7·8	7·8	7·8
9·10	9·10	9·10	9·10	9·10²⁰	9·10	9·10
11·12	11·12	11·21	11·12	11·12	11·21	11·12
13·14	13·14	13·14	13·14	13·14	13·14	13·14
15·16	15·16	15·16	15·16	15·16	15·16	15·23
17·18	17·2	17·18	17·18	17·18	17·18	17·18
19·20	19·20	19·20	19·20	19·20¹⁰	19·20	19·20
21·22	21·22	12·22	4·22	21·22	4·22	21·22
23·24	23·24	23·24	23·24	23·24	23·24	16·24

D. stramonium—continued

D. quercifolia
(12 races)

PT 94 (1 race)	PT 95 (1 race)	PT 2 + PT 3 (62 races)	Type 1 (6 races)	Type 2 (3 races)	Type 3 (3 races)
1·14	1·2²⁰	1·18	1·18	1·18	1·18
3·4	3·4	3·4	3·4	3·4	3·4
5·6	5·6	5·6	5·6	5·6	5·6
7·8	7·8	7·8	7·20	7·20	7·8
9·10	9·10	9·10	9·10	9·2	9·10
11·12	11·12	11·21	11·21	11·21	11·21
13·18	13·14	13·14	13·14	13·14	13·14
15·16	15·16	15·16	15·16	15·16	15·16
17·2	17·18	17·2	17·2	17·10	17·2
19·20	19·20²	19·20	19·8	19·8	19·20
21·22	21·22	12·22	12·22	12·22	12·22
23·24	23·24	23·24	23·24	23·24	23·24

D. ferox
(16 races)

D. discolor
(4 races)

D. leichhardtii
(7 races)

D. pruinosa
(1 race)

Type 1 (13 races)	Type 2 (3 races)	Type 1 (1 race)	Type 2 (6 races)
1·18	1·21	1·11	1·18
3·4	3·4	3·4	3·4
5·6	5·6	5·6	5·6
7·20¹⁶	7·20¹⁶	7·8	7·8
9·10	9·10	9·10	9·10
11·21	11·18	12·22	11·16
13·14	13·14	13·14	13·14
15·16²⁰	15·16²⁰	16·18	15·12
17·2	17·2	17·2	17·2
19·8	19·8	19·20	19·20
12·22	12·22	21·15	21·22
23·24	23·24	23·24	23·24

* These chromosomes are identical with those left blank in *D. pruinosa*, but their end arrangements have not yet been determined.

are 5 recurrent types of *D. stramonium* found in nature. There are also 5 prime types which have been found only once and hence may be considered sporadic. The interchanged chromosomes of one of these are not included in the table, since the chromosomes of the interchange have not yet been determined. The other species of *Datura* have been tested in much the same way. For each a tester type has been established as a standard, and with it the number of chromosomal types in the given species can be determined. Later by the use of proper testers from *stramonium* the interchanged chromosomes of these species have been determined. The interchanged chromosomes of *D. quercifolia* and *D. ferox* can be relatively easily determined, since there is no difficulty in getting F_1 hybrids with tester races of *D. stramonium*. *Datura discolor* also crosses readily with testers of *D. stramonium* when it is used as a male. There is considerable difficulty, however, in getting a cross between *D. stramonium* and *D. leichhardtii*, and this is possible only when *D. leichhardtii* is the female parent. *Datura pruinosa* will not cross with *D. stramonium*, but we have succeeded in making a partial analysis of its interchanged chromosomes by using *D. leichhardtii* as a bridging species and getting the chromosomes of *D. pruinosa* into the matrix of the *D. leichhardtii* protoplasm, which will allow crosses with *D. stramonium* testers. It will be noted that in the table there are blanks for 3 chromosomes in *D. pruinosa* and in the second type of *D. leichhardtii*. We know that the chromosomes in these two types are modified in the same way, but it will be necessary to make one further cross in order to be sure of the exact order of the interchanges involved. We have under investigation ten herbaceous species of *Datura*. In addition to those listed in the table, there are 3 chromosomal types among 42

races of *D. innoxia* tested; 3 types among 31 races of *D. meteloides*; and 5 types among 60 races of *D. metel*. *Datura ceratocaula* has only 1 type among 2 races tested. The last species mentioned we have not yet surely succeeded in inducing to hybridize with any other *Daturas*, although histological study shows that fertilization is initiated and seeds have been secured from crosses. The difficulty may lie in the low percentage of germination of seeds of *D. ceratocaula*. This difficulty has now been overcome for the pure species, and we hope to secure hybrids either by better methods of germination of the hybrid seed or by growth of young proembryos on artificial media by the methods of Drs. van Overbeek and Conklin.

It will be noted from the table that interchanges have been found in all species in which a sufficiently large number of races have been obtained. Not all the 12 chromosomes of our standard PT 1 are involved in interchanges with the same frequency. Thus it will be observed that, in the species in the table, the 5·6 chromosome is the only one not involved in an interchange. There are only 2 modified chromosomes related to the 23·24 chromosome, 3 to the 3·4 chromosome, and 4 to the 13·14 chromosome; yet there are 6 modified chromosomes related to the 17·18 chromosome, 7 to the 1·2 chromosome, 8 to the 21·22 chromosome, 9 to the 11·12 chromosome, and 10 to the 15·16 chromosome.

Our earlier table of the geographical distribution of prime types in *D. stramonium* shows that there is a certain amount of localization of these types throughout the world. Thus, PT 1, which is not duplicated in other species, is the predominant type only in the United States, Brazil, and Japan. Prime Type 2 is the predominant type in other parts of the world. Prime Type 3 is found associated with PT 2

throughout Peru. The 1·18 and 2·17 chromosomes of PT 2 are found in *D. quercifolia*, *D. ferox*, *D. leichhardtii*, and *D. pruinosa*; the 2·17 chromosome is found in *D. discolor*. It would appear, therefore, that the PT 2 of *D. stramonium* would have been a better standard in that it is more likely to represent the type to which other races and species are related than does the PT 1 which we chose as a standard. It is of interest to note that so far as the end arrangements of their chromosomes are concerned, the third type of *D. quercifolia* is identical with the races of *D. stramonium* from Peru, which are made up of a combination of PT 2 and PT 3. The modified chromosomes of the Peruvian type are also represented in the end arrangements of the first type and of part of the second type of this same species. They are also represented in *D. ferox*. One of the modified chromosomes of PT 3 and one of PT 2 are also represented in *D. discolor*. It is perhaps of significance that the geographical distribution of the Peruvian type, which runs up also into Mexico, overlaps the distribution of *D. quercifolia*, *D. ferox*, and *D. discolor*. There is certain suggestive evidence also from the morphological standpoint which would add some weight to the suggestion from the interchanged chromosomes that there is a relationship between these three species and the Peruvian race of *D. stramonium*. The last two species in the table, *D. leichhardtii* and *D. pruinosa*, are obviously rather closely related in morphological characteristics. The first is endemic in Australia, the second is endemic in Mexico. *Datura pruinosa* seems to be closely related to especially the second type of *D. leichhardtii* in its interchanged chromosomes. Likeness of the end arrangement of their chromosomes cannot be used, however, as a dependable criterion of the taxonomic relationship. If the first type

of *D. leichhardtii*, for example, were crossed with PT 2 of *D. stramonium*, there would only be a single circle of 4 chromosomes, indicating that all the chromosomes except 2 in the two species had the same end arrangements. Although segmental interchange has apparently not been the cause of differentiation of species, it has accompanied such differentiation and in some ways appears to be a factor in evolution.

In figure 1 are listed the configurations in a series of crosses involving the species *D. innoxia*, with other species and with testers of *D. stramonium*. These crosses will serve as an example of the extreme difficulty involved in determining the chromosomal end arrangements of the species which do not readily cross with the testers of *D. stramonium*. A single test now under way should determine the chromosomes left blank in the table for *D. pruinosa* and *D. leichhardtii*, which have been tested against two types of *D. innoxia*. *Datura innoxia* will not cross directly with *D. stramonium* but will cross readily with *D. leichhardtii*. Accordingly we have made repeated backcrosses of the *D. stramonium* testers onto *D. leichhardtii* in order to secure the *stramonium* tester chromosomes in a matrix of *leichhardtii* protoplasm. Our intention had been, after several backcrosses to *leichhardtii*, to isolate these tester races in homozygous condition from the selfed offspring of heterozygous parents. A difficulty has arisen in that we have found it difficult to transmit the modified chromosomes of the majority of these testers through the pollen, although they will come readily through the female parent. The heterozygous plants from repeated backcrosses are near enough like *D. leichhardtii* so that they will cross with *D. innoxia* when used as females. Half of the offspring should carry the tester chromosomes. When the crosses in-

dicated on the right-hand side of the diagram have been made and the chromosomal configurations in the hybrids determined, it should be possible to determine the chromosomal end arrangements of the races of *D. innoxia*. The same method is applicable to the races of *D. meteloides*, for which we have already made a consid-

erate number of tests. A somewhat similar treatment should be possible for *D. metel* after the races of *D. innoxia* and *D. meteloides* have been cleared up.

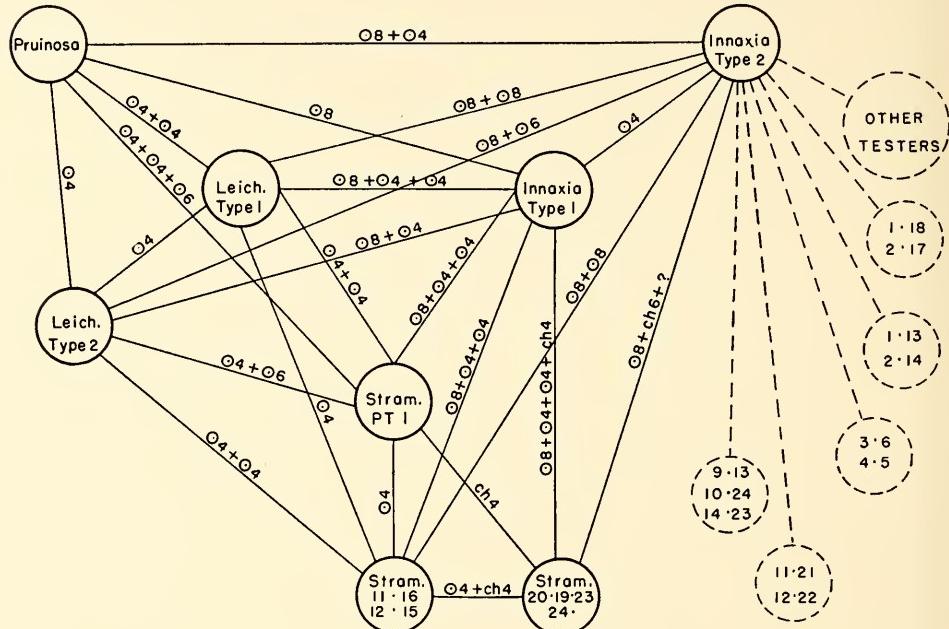


FIG. 1. Tests for interchanged chromosomes in *Datura innoxia*. The $2n$ chromosome number in all *Daturas* is 24. Configurations of 4 or more chromosomes in F_1 's are listed on lines connecting parents. Closed circles are represented by the sign \circ followed by the number in the circle. Ch is abbreviation for open chain. The paired chromosomes are not represented. Dashed lines and circles at right represent projected crosses to selected testers with modified chromosomes, which should complete the determination of the chromosomes in *D. innoxia*.

erable number of tests. A somewhat similar treatment should be possible for *D. metel* after the races of *D. innoxia* and *D. meteloides* have been cleared up.

The study of the occurrence of interchanged chromosomes in species of *Datura* is the only investigation of this scope that has been undertaken with plants. It gives us, however, only a partial picture of the changes in the chromosomes which

determined by two other methods. Dr. Bergner is endeavoring to work out a technique whereby the chromosome may be adequately stained for comparison of paired strands at early prophase divisions. If such a technique is discovered, it should be possible to match up homologous parts of adjacent paired chromosomes through chromomere similarity and to determine the extent of inverted sections as Dr. Mc-

Clintock has been able to do by use of special technique with maize chromosomes. Another method of determining inversion changes which is under way is the reduction of crossing over brought about by inversions, which we trust may be detectable through the use of pollen-abortion genes and viable gene-type testers.

POLYPLOIDY AND THE SEX MECHANISM IN MELANDRIUM

Dr. Warmke has continued his studies on sex differentiation in the dioecious species *Melandrium dioicum*. In this he has isolated two new chromosome types: 2A XYY (male) and the type with an extra fragment 2A XXX^tY (hermaphro-

ditic-male). The first of these is important in studying the synaptic relationships of two Y chromosomes in a diploid individual, which has not been possible heretofore. It also provides a means of comparing XY and YY synaptic affinities. The second type, 2A XXX^tY, is important in providing confirmatory evidence for the presence of female genes in the X chromosome by completing the diploid series:

Chromosome constitution	Sex
2A XY	Male
2A XXY	Male
2A XX ^t Y	(occasional ♀ blossom)
2A XXX ^t Y	Hermaphrodite (occasional ♂ blossom)

THE GENE

M. DEMERECK, B. P. KAUFMANN, EILEEN SUTTON, AND U. FANO

X-ray and ultraviolet radiations are still the best known agents for inducing changes in genes and chromosomes, and they have been utilized extensively in the researches of the past year. In order to take full advantage of the physical possibilities, we have again cooperated with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, in experiments with monochromatic ultraviolet radiation; with Dr. P. A. Cole, of the same Institute, in experiments with ultraviolet photometry; and with Mr. L. D. Marinelli, of the Memorial Hospital, New York, in experiments in which refined measurements of X-ray intensity were required.

CORRELATION OF DATA ON CHROMOSOMAL CHANGES

It was suggested in Year Book No. 38 that the observed deficiencies produced by 2500 to 3000 roentgens, which involve the Notch locus, might arise by either of

two different processes. The longer deficiencies would correspond to the usual chromosomal aberrations involving two independent breaks and would be classified as "two-event" processes. The short ones, which are particularly frequent, would arise from some different "single-event" process, and would correspond more closely to the mutations affecting the Notch locus which are not cytologically detectable deficiencies. Since the last report a large number of additional changes at the Notch locus has been accumulated, and these cases have been investigated by Dr. Demerec and Dr. Fano to determine the approximate length of single-event deficiencies. Comparison of data by Dr. Kaufmann and Miss Bishop supports the theoretical expectation that the inversion and the deletion of any given chromosome fragment are equally probable. The existing data on the frequency of inversions enable us to evaluate the expected fre-

quency of two-break Notch deficiencies. Comparison with the Notch data shows that only those Notch deficiencies covering more than about 15 salivary-chromosome bands can be attributed to a two-break process. Shorter deficiencies must be due to some other process, whose frequency should depend, to a smaller degree, on the X-ray dosage. Spontaneous Notches should not involve two-break processes since the frequency of two-break chromosome rearrangements is negligible in untreated sperm. In fact, the largest deficiency observed among spontaneous Notches covers 13 bands, which is just below the limit of 15 bands set for single events. The length of 15 bands is about 6 microns in salivary-gland chromosomes and should probably be about 100 times smaller in the chromosomes of the sperm, that is, approximately 600 Å. Thus a single-event process may have a radius of action of about 600 Å.

The sterility induced in the sperms of *Drosophila* by radiation, that is, the production of "dominant lethals," is thought to be mainly due to chromosomal changes. Dr. Fano has considered, on the basis of the available data, whether most of the observed dominant lethals can be attributed to chromosomal rearrangements which are nonviable because they lead to the loss of large fractions of chromosomes, but are otherwise analogous to the observed viable rearrangements. A negative answer must be given to this question. Since, on the other hand, dominant lethals connected with no chromosomal rearrangement must be relatively rare, if they occur at all, one is inclined to conclude that dominant lethals frequently involve some as yet unobserved type of chromosomal rearrangement. Several facts, among which are the rate of production of dominant lethals at low dosage reported in Year Book No. 39 and the very low observed frequency

of terminal deficiencies and losses of whole chromosomes, suggest the existence of some effect of single chromosome breaks which is more damaging than the simple loss of a part or the whole of a chromosome.

The correlation of dominant lethals with the observed chromosomal rearrangements requires a preliminary understanding of the production of such rearrangements. A further discussion of the existing data on cytologically detected rearrangements showed that the production of chromosomal rearrangements does not fit well into any simple scheme.

The order of magnitude of several quantities related to chromosomal changes has been evaluated by Dr. Fano on the basis of existing data. A chromosomal break occurring sufficiently close to a genetic locus may affect its phenotypical expression. An appreciable amount of data on the frequency of this process has been collected by Dr. Demerec, especially for the Notch locus. The frequency of breaks along all the chromosomes is approximately known from cytological data. One can then estimate that a fraction of the order of 1/10 of all breaks occurring sufficiently close to a locus affects its phenotypical expression. This fraction seems to be larger for the cut than for the Notch locus, but it appears to be independent of whether the locus is transferred into euchromatin or heterochromatin. In the case of heterochromatin, however, it is not necessary that the break be adjacent to the changed locus. Comparison of cytological data on the frequency of euchromatic X-chromosome breaks with the data on the frequency of sex-linked lethals shows that both of these frequencies are approximately 8 per cent in sperm treated with 3000 r X rays. Since at this dosage approximately one-third of the lethals have been shown to be connected with a chromosomal rearrangement, it appears that about one out of every three

X-chromosome breaks is associated with a lethal change.

DOMINANT LETHALS

The experiments on dominant lethals by Dr. Fano and Dr. Demerec reported in Year Book No. 39 were continued and expanded. Attempts were made to investigate and reduce the sterility of untreated material, with a twofold purpose. On the one hand, any reduction of spontaneous sterility and of its variability affords a more accurate measurement of induced dominant lethals. On the other hand, full understanding of the sterility phenomenon is essential to an evaluation of its selective influence on the genetic material. Spontaneous sterility was not easily brought under control, and appeared to be affected by environmental, individual, maternal, and hereditary factors. Experiments on this subject are still under way. The large variability observed in the sterility phenomena might seriously affect the accuracy of the quantitative discussion of genetic experiments.

The semilogarithmic plot of the residual fertility as a function of X-ray dosage is approximately a straight line in the range of high dosage, between 5000 and 11,000 r, but does not fit a single straight line at all dosages. This seems to indicate that most of the sterility effect, but not all of it, is due to a "single-event" process.

The data of Drs. Demerec and Kauffmann on the sterility induced in mature and immature sperm were extended by further experiments. Young males were treated with X rays at 4000 r. Approximately 4000 sperms used shortly after their irradiation in fertilizing eggs gave only about 20 per cent viable embryos, but 3200 sperms tested 24 days later proved to be about 80 per cent fertile, that is, as fertile as the controls. This indicates that the for-

mation of sperm carrying dominant lethals is selected against during the maturation divisions, as compared with the formation of normal sperms. No restoration of fertility should then be expected when the amount of sperms free from chromosomal changes is so small that it cannot produce any appreciable fertility even when the sperms carrying dominant lethals have been eliminated. This last expectation has been verified by experiments at 20,000 r or more, in which no fertility was detected at any time after irradiation; one would hardly expect that even a single spermatogonial cell would escape chromosomal changes.

HIGH-DOSAGE EXPERIMENTS

Since the experiments with dominant lethals showed the existence of an appreciable residual fertility among the sperms of males irradiated with 11,000 r, it was decided to conduct a series of experiments with heavy X-ray treatments up to 12,000 r. This project had a twofold purpose. On the one hand, the occurrence of hereditary changes among the surviving offspring of heavily treated males is expected to be so large that it affords an especially good opportunity to study a large number of individual changes *per se*. On the other hand, the comparison of all the changes obtained at 12,000 r with those obtained at the usual lower dosages (about 3000 r) might afford a good opportunity to detect any possible shift in the relative frequency of different types of changes. It was originally planned to investigate the following points: (1) the absolute and relative frequency of cytologically detectable changes associated with the phenotypical character Notch; (2) the absolute and relative frequency of chromosomal rearrangements associated with sex-linked lethals; (3) the absolute and relative frequency of different

types of cytologically detectable chromosomal rearrangements. The numerous experiments hitherto completed showed that the occurrence of chromosomal changes among the surviving offspring of heavily treated males is not consistently so high as was expected. This finding required a large amount of preliminary work directed to the investigation of technical factors which might reduce the observed frequency of changes.

A series of tests for sex-linked lethals among the offspring of males irradiated with dosages varying from 4000 to 12,000 r were carried out by Drs. Demerec and Fano. They did not succeed in duplicating the results of previous authors who had reported a frequency of lethals reaching as high as 35 per cent. The tests which were carried out with the standard CIB procedure did not yield a frequency larger than about 10 per cent.

The results obtained by cytological analysis of salivary-gland chromosomes in larvae derived from fathers receiving high X-ray dosages are also somewhat confusing. It was anticipated on two bases, (1) egg mortality induced by dominant lethals, and (2) extrapolation of the curves obtained in the 1000- to 5000-r dosage range, that a very high percentage of all larvae derived from fathers treated with 12,000 r would contain deranged chromosomes. However, the 41 per cent of altered sperm among the first sample of 100 glands analyzed by Dr. Kaufmann is essentially the same as the frequency obtained at the 5000-r level (see Year Book No. 37), although the number of breaks per 100 sperm (161) exceeds somewhat that obtained in the 5000-r material (125 to 144). Before any effort can be made to interpret such findings, a considerably larger amount of data must be collected, not only because of the low values but also because of considerable heterogeneity with respect to

the number and types of breaks which were obtained in the three different experiments from which these 100 pairs of glands were obtained.

COMPARISON OF BREAK FREQUENCY INDUCED IN SWEDISH-B AND OREGON-R STOCKS

Experiments by Dr. Demerec reported in Year Book No. 36 showed that when wild-type flies of the Oregon-R stock were treated with X rays, the frequency of X-chromosome lethals was lower than when several other wild-type stocks were treated. As an example, the rate for Oregon-R was about half of that for the Swedish-b. On the contrary, the frequency of dominant lethals induced by X rays, as measured by the death rate during ontogeny, was higher in the Oregon-R stock than in the simultaneously treated Swedish-b material (Year Book No. 37). Since dominant lethals are in general referable to chromosomal derangements, and since some of the sex-linked lethals may also involve gross chromosomal changes, a cytological analysis was undertaken by Dr. Kaufmann of the salivary glands of larvae derived from the two kinds of treated males. Material useful for this purpose was available from several other experiments in which Swedish-b and Oregon-R males were treated simultaneously with about 4000 roentgens and then mated with Swedish-b females. Analysis of about 245 pairs of glands from each of the two crosses yielded approximately equal percentages of altered sperms ($35.5 + 3.06$ for Swedish-b and $38.62 + 3.10$ for Oregon-R). But whereas the Swedish-b glands showed 82.04 breaks per 100 pairs of glands, the usual value for 4000 r, the Oregon-R material gave 103.24 breaks per 100 glands. These values indicate that the types of changes observed following irradiation of the Oregon-R sperms are on the average

more complex than those detected following irradiation of the Swedish-b sperm. The reason for these differences remains to be determined. The possibility is now being tested that hybrid vigor in the Swedish-b/Oregon-R larvae is conducive to survival of more individuals containing complex chromosomal rearrangements than obtains in the homozygous Swedish-b larvae.

THE *y-sc* REGION OF THE X CHROMOSOME

The cytogenetic analysis by Dr. Sutton of X-ray-induced changes in the *y-sc* region indicates that the *y* and *ac* loci lie within the region 1 A5-8 of the salivary map, and that the *sc* locus is probably associated with the doublet 1 B3-4.

Of 12 changes in the *y* locus, 4 were not accompanied by any detectable chromosome abnormality, 3 were due to deficiency, and 5 were due to "position effects." On the other hand, 14 *sc* changes included only 1 case which appeared cytologically normal and 2 cases of deficiency, the remaining 11 examples being due to "position effect" (gross rearrangements). The *sc* locus thus appears to resemble the *ct* locus, which is found to be very susceptible to changes in position, as opposed to the *y* and *N* loci, which are less frequently affected by such changes.

RECOVERY OF SIMPLE BREAKS

In an attempt by Miss Maydelle Bishop to obtain simple terminal chromosome breaks in *Drosophila melanogaster*, advantage was taken of the fact that females hyperploid for the right end of the X chromosome in the Bar-carnation region are as viable as the normal female (Patterson and others, 1935). This allows one to design an experiment such that single breaks in the forked-carnation region have viability equal to or greater than that of

double breaks involving this region and some other region of the X chromosome, in so far as their viability is determined by hyperploidy. Wild-type males were irradiated with either 2000 or 4000 roentgens and Bar males with 1000, 2000, or 4000 roentgens, and mated to yellow vermilion forked carnation (*y v f car*) attached X females. In all, 48,081 F₁ females were examined, among which 358 two-break hyperploid females (*v f car*, *f car*, *car*, and *v f* females) were found, and 21 apparent one-break hyperploid females (*y v f*, *y v*, and *y* females). Obviously the known double breaks outnumbered the apparent single breaks, although both the viability and chance expectation would lead one to expect the opposite result. It is impossible to say how many apparently single-hit cases are actually of that type, but some conclusions can be reached by analyzing the data. The probability that the *y v f* hyperploids are derived from deletions having a second break distal to the leftmost marker yellow may be tested by comparing that class with the *v f* hyperploid class. The probability of the right break in the forked-carnation interval is the same in each case, but for the left break there are only 3 or 4 bands to the left of yellow as compared with approximately 300 bands (counting double bands as one) between yellow and vermilion. As the left break approaches vermilion, the viability of the hyperploid *v f* females is decreased. But the interval from white to yellow, which has been shown to have little effect on viability of hyperploid females, has about 100 bands; therefore *v f* hyperploid females with the left break between yellow and vermilion should be many times as frequent as *y v f* hyperploid females with the left break between the tip of X and yellow. Actually they are only slightly more than twice as frequent (36 *v f* as compared with 16 *y v f*). Another possibility is that a second break may

be to the right of the centromere in the small arm of the X. The probability of this type of deletion should be about the same as for a second break in the region distal to yellow, unless the short arm is much longer than has been supposed, or has an exceptionally high break frequency. This comparison leads to the conclusion that some if not most of the apparent single breaks are actual. Supposing that single breaks are responsible for dominant lethals, the data of Fano and Demerec (1941) may be used to compute roughly the expected frequency of any class of single breaks. The calculated single-break frequency in the forked-carnation region is 0.08 per cent at 4000 r. Actually about 0.05 per cent are recovered. In other words, about 1 out of 20 single breaks "heals" and is picked up in the next generation. Calculations of Fano using Sutton's data on tip deficiencies, involving an entirely different region, length of interval, and method of detection from that in the present work, show the same factor of 20. The incidence of non-yellow deletions may be compared with Kaufmann's unpublished data on the occurrence of inversions involving the same region to test the assumption of Demerec and Fano (1941) that deletions and inversions occur with approximately equal frequency. The incidence of deletions and inversions agrees within a factor of about 2, the percentage of deletions being slightly higher.

EXPERIMENTS WITH ULTRAVIOLET RADIATION

This is a cooperative project with the National Institute of Health, in which Dr. M. Demerec, Dr. A. Hollaender, Mrs. M. Houlahan, and Miss M. Bishop are taking part. During the past year experiments were completed in which *Drosophila melanogaster* males were treated with

monochromatic radiation of 3050, 3130, and 3300 Å and the effect on hereditary changes was observed through lethals induced in the X chromosome. In the experiments done earlier and reported in Year Book No. 39, the effect of 2280, 2650, and 2937 Å was investigated. All these wave lengths are effective in producing lethals which may with good reason be assumed to be caused by changes in genes.

Some sterility was induced by all wave lengths tested, shorter wave lengths proving to be more effective than the longer ones. A sharp break in the effectiveness took place between 3050 and 3130 Å. Sterility is apparently due to injury produced in the tissues by radiation which penetrates the abdominal wall. The energy required to produce sterility at 2280 Å is about 2.1×10^6 ergs per cm.², and the sterility limit is so low that only 1 per cent of lethals can be obtained. At 3130 Å, energy of 83.5×10^6 ergs per cm.² can easily be applied, since it sterilizes only about 50 per cent of the treated males. Such dosage induces about 5.5 per cent lethals. Yellow-white flies showed higher sensitivity to injury than wild-type flies.

For 3130 Å, data are available indicating that the genetic effect increases with the dosage applied, but that the interference of secondary factors induces a great deal of variability in successive experiments. This is probably caused by the absorption of radiation by the tissues which happen to cover the testes during irradiation. In occasional experiments the percentage of lethals obtained was as high as 50, indicating the possibility that ultraviolet may produce mutations at a very high rate.

In one experiment with 2650 Å, one translocation among 116 treated sperm was observed. An additional 762 tests of sperm from males which had been given similar treatment did not disclose any translocation. None was observed among 1073

sperm obtained from males treated at 3130 Å with energy which produced 5.5 per cent lethals. Thus these experiments gave further support to the assumption that ultraviolet radiation is effective in inducing gene changes but is not effective in producing breaks in chromosomes.

Preliminary studies of the absorption of ultraviolet radiation in the salivary-gland chromosomes have been made by Dr. Sutton in collaboration with Dr. P. A. Cole, of the National Institute of Health, Bethesda, Maryland. It has been shown by Caspersson and Schultz that the chromosome bands contain a protein component (indicated by an absorption maximum at 2800 Å) as well as the nucleic acid component (absorption maximum at 2650 Å). Caspersson (1940) has also shown that different types of protein are found in different regions of the chromosomes. The results obtained at Bethesda indicate that the concentration of protein, as well as of nucleic acid, in the bands is high.

Stocks raised at 18° C. show great variability of nucleic acid content, both between homologous bands and within bands.

In order to determine the relation of nucleic acid content to the phenomenon of variegation, it is proposed to measure the absorption of bands in a white-mottled stock carrying modifiers which enhance or decrease the phenotypic variegation.

MOTTLED IN THE SECOND CHROMOSOME

In the F₁ from *ri p^w* flies irradiated at 4000 r, an individual female was recovered by Mr. T. Hinton which showed an eye containing areas of disarranged facets lighter in color than peach, and within these areas, occurring singly or in groups, facets extremely dark or black in color. Two other similar flies were found in the first 9000 examined, but were not viable. A stock was obtained from the viable

mutant, the salivary-gland preparations from which showed an interbrachial inversion in the second chromosome. The break in 2L is immediately proximal to the 2D₁ band. The break in 2R is at 41A/B. Since the 41 of 2R is heterochromatic, the inversion causes both the bands which are proximal to and distal to the break at 2D₂ to lie adjacent to heterochromatin. The aberration being in the second chromosome and the peach locus on the third, a separation of the peach locus from the mottled effect was undertaken by Mr. K. C. Atwood. The third chromosomes were replaced by wild-type third chromosomes by the use of dominant markers. The jumbled facets and black-spotted appearance were found still to occur with wild-type eye color and with Plum. The mottling effect was more extreme in flies raised at 15° C. than in those raised at room temperature. The aberration is lethal when homozygous. It has already been shown that heterochromatin can cause genes to show mottling. An attempt was therefore made in this case to discover which genes were near enough to the aberration to be thus affected. It is possible that *clot* (locus 16.5) is responsible for the dark-colored facets, and *pied* (17.5) for the roughness of the facets. This interpretation implies that the wild-type alleles are producing in the somatic cells a dominant *cl* and a dominant *pi* effect.

TERMINAL ADHESIONS IN SALIVARY-GLAND CHROMOSOMES

A study has been made by Hinton and Atwood of terminal adhesions in salivary-gland chromosomes. Relative frequencies of the possible combinations differ in the Oregon-R and Swedish-b strains of *Drosophila melanogaster*. Data from the F₁ of Oregon-R males by Swedish-b females agree with those from Oregon-R, indicat-

ing a dominance of Oregon-R chromosomes with respect to terminal adhesions. When males were compared with females of their own stock, the autosomes were found to behave alike in both, but the percentage of adhesions involving the X chromosome was much smaller. When a Swedish-b stock carrying a homozygous deficiency for the tip of X was compared with normal Swedish-b, the relative frequencies of combinations were found to be altered. At least four different self-specific factors at the chromosome tips must be postulated to explain the *melanogaster* data. Chromosome arrangement in the nucleus and the state of chromosome ends in the unsmeared nucleus have both been eliminated as interfering factors. Chromosome length as a factor is being tested. From 200 cases of terminal adhesions found in *D. pseudoobscura*, a nonrandom occurrence of the various combinations was also established for this species.

UTILIZATION OF SPERM BY THE FEMALE DROSOPHILA

The analysis of the biological factors involved in sperm transfer and utilization reported in Year Book No. 39 has been extended. These experiments were undertaken to measure some of the determinable factors which might be responsible for the variability that occurred in different experiments in which males of *Drosophila melanogaster* had received similar treatment. Last year's report considered the time needed for the male to exhaust the supply of mature sperm. The considerable variability in the proportions of fertile and sterile eggs laid by different females following a single insemination by an irradiated male suggested that the production of dominant lethals might not be wholly responsible for the sterility, but that it might depend in part on the deposition of

unfertilized eggs. A further study of this point has been made by Drs. Kaufmann and Demerec, using wild type, Swedish-b males which had not been irradiated. Each of these males mated successively with three females, A, B, and C. Following copulation the female was isolated and counts were made of the number of eggs which she deposited and the number of larvae hatching therefrom. It was found that the amount of sperm transferred in a single copulation is only sufficient to guarantee fertilization of a high percentage of the eggs laid during the first few days of laying, that on subsequent days the proportion of sterile eggs increases, and that toward the end of the egg-laying period practically all the eggs deposited are unfertilized. Similar data have been obtained using irradiated males.

An effort has also been made to measure the relative ability of sperms stored in the seminal receptacles to take precedence over sperms subsequently deposited in fertilizing the eggs. For these tests, plexus brown speck females were provided with wild type, Curly/Glazed, and *px bw sp* males in all the possible mating sequences. Among the progeny obtained, Curly and Glazed were slightly more frequent than the wild type, but *px bw sp* represented only about one-sixth of the total. Similar ratios were obtained when three females, one fertilized by each of the three types of males available, were permitted to lay their eggs in the same bottle. Since in these controls there could be no competition of different types of spermatozoa, it seems that the high frequency of wild type and *Cy* or *Gl* and the dearth of *px bw sp* flies hatching from the eggs laid by polyandrous females are to be attributed to differential viability of the different types of embryos and larvae, and not to differences in vigor or mortality among the various types of spermatozoa tested, which might lead to

such selective fertilization as Lobashov believed was occurring in similar experiments which he had conducted.

LARVAL PIGMENTATION

Pigmentation of the larval mouth parts and spiracle sheaths has been studied by Dr. K. S. Brehme in the mutants of *Drosophila melanogaster* which affect adult body color. In general, the mutants whose adult body color is lighter than wild type are characterized by lighter pigmentation of the larval mouth parts; the tan alleles, straw² and straw³, and all the yellow alleles except *y*^{34c} show this effect. The greatest difference from wild type is seen in the cases of *y*^{35a} and *y*²⁶⁰⁻²⁸, although the adults of these genotypes are not markedly lighter in color than the other extreme yellow alleles, such as *y* or *y*⁴. Certain of the mutations which lighten the body or bristle color of the adult do not affect the larval jaws: *svr*, T(1;2)*Bld*, *stw*, *stw*⁴, and *y*^{34c}. Larvae whose mouth parts are markedly lighter than wild type are readily classifiable in the third instar, and the difference is already discernible at hatching from the egg. Of the mutants with darkened adult pigmentation, only the ebony alleles increase the pigmentation of the larval jaws. The ebony alleles considerably darken the spiracle sheaths at all stages of development.

The Malpighian-tube color of 33 eye-color mutants has previously been reported by other investigators. Because of the usefulness of this character in classifying larvae for experimental purposes, observations have been made by Drs. Brehme and Demerec of 66 additional mutants, virtually completing the list of factors affecting eye color. No direct relation was found between the amount of pigment in the eye and that in the tubes. Alleles which have a similar effect on eye color, for ex-

ample the *ras* alleles, appear to have a similar effect on tube color, whereas alleles which have a different effect on eye color (the white series) affect tube color in varying degrees, and in this case dark eye color is not necessarily accompanied by dark tube color. Two useful chromosomal aberrations are readily classifiable in the larva: T(2;3)Pale (white tubes) and In(3L)persimmon (almost white).

INTERNAL ANATOMY

The internal anatomy and histology of adult wild type (Swedish-b) *Drosophila melanogaster* were studied by Dr. Albert Miller. As a contribution toward a monograph on the biology of this species, a descriptive account illustrated by drawings and photomicrographs has been prepared for each organ system, namely, the digestive system, circulatory system and associated organs, respiratory system, muscular system, nervous system, and male and female reproductive systems. Manual dissection of living and fixed material and serial microtome sections were employed in this study. Each system has been drawn as a whole as viewed in lateral, dorsal, or ventral dissection to show its component parts and normal topographical relations within the body, and photographs have been prepared to show the histological details as seen in stained sections. The description of each system includes an account of the organs, their location and interrelations, their microscopic anatomy, and the visible developmental or physiological changes that occur during adult life.

In conjunction with the study of the male reproductive system, a special investigation was conducted to determine the position of the testes in the living fly and the effect of compressing the abdomen to secure better exposure of the sperm-containing organs during irradiation with soft rays.

It was found that normally only certain portions of the testes lie near the body wall and the seminal vesicles are surrounded by the testicular coils; also that the degree of expansion of the crop influences the segmental position of the testes. Flattening the abdomen effects a maximal spreading of the testes against the ventral body wall when the crop is undistended by food. Thus optimal exposure of the testes to poorly penetrating rays should be attained by irradiating the ventral surface of undistended flies when the abdomen has been flattened by dorsoventral pressure. Cuticula, epidermis, a single layer of muscle fibers, fat tissue, and the testicular sheaths (totaling 20 to 60 microns in thickness in an uncompressed state) intervene between the sperm and the source of radiation.

EDUCATIONAL PROJECT

Through the initiative of Dr. Bush, *Drosophila* stocks have been made available to laymen and students of biology for simple experimentation on heredity. It has been felt that such an experimental approach to the subject of heredity—at first, in all probability, for the verification of established principles—will help toward a better understanding of the fundamental laws concerned, and may lead subsequently to the collection of data applicable to the solution of current research problems.

A short article was published in the May 1940 issue of the *American Biology Teacher* outlining the new project. This

article was abstracted by *Science Service*, *Science Digest*, and *Science Observer*, and thus made widely known. A 35-page pamphlet was printed by this Institution describing the life history of *Drosophila* and the methods used in breeding and in cytological research. Two sets of mimeographed directions for experiments were also prepared. The first set gave an outline for simple experiments showing mono-hybrid and dihybrid ratios, and the second set described more advanced experiments demonstrating dominance, linkage, and sex linkage.

In answer to each request, a copy of the pamphlet, the first set of outlines, and cultures with flies were sent, and when the first set of experiments was concluded the material for the advanced set was mailed on request. Extra copies of the pamphlet are on sale at the Office of Publications. A number of colleges used the pamphlet in the laboratory course in genetics, so that the first edition was soon exhausted and the second edition was printed early in the summer of 1941.

During the past year 220 shipments of cultures were made. They were sent to 34 states, the District of Columbia, Puerto Rico, and Canada. The largest number of shipments went to New York state (89), Pennsylvania (17), Illinois (14), Ohio (9), Kansas (8), Massachusetts (7), Missouri (6), and New Jersey (6). High schools and science clubs in high schools received 122 shipments, colleges received 33, and individuals 65.

ENDOCRINE STUDIES

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H. H. DUNHAM, AND D. F. OPDYKE

Regulation by hormones occurs in perhaps all phases of life, and certainly it is very prominent in development, growth, reproduction, and bodily maintenance.

The pituitary gland is known to assist in regulating all these four large aspects of life, though the number of its hormones and some of the effects produced by them

are still unknown. It is especially in the sphere of maintenance that the greatest uncertainty now exists as to the nature and number of participating pituitary hormones, and until these questions are clarified there will be doubt concerning the hormones actually concerned in the regulation of development and growth, and likewise a lack of understanding of the abnormality and disease which attend pituitary failure in the sphere of maintenance. For these reasons the present report, besides noting progress on other studies, gives more than usual attention to results of an examination of the hormones concerned in the metabolism of carbohydrate and fat.

PITUITARY INFLUENCE ON METABOLISM OF CARBOHYDRATE AND FAT

The anterior pituitary fractions obtained by ammonium sulphate precipitation which were found by Young (1939) to be either "diabetogenic" or inactive in the dog, and the similar fractions tested by Campbell and Keenan (1940) for their ability to produce fatty livers and ketosis in mice, have been extensively studied. At this time it seems that an intensive study of these particular fractions is the most promising way to obtain further light on the relation of the pituitary to experimental diabetes. We have therefore repeatedly prepared such protein fractions and carefully assayed them (2-day chicks, pigeons, rats) for prolactin, gonadotrophin, thyrotrophin, adrenotrophin, and posterior-lobe hormones, and also simultaneously tested each fraction for the several following actions: ability to induce (*a*) prompt (at 4 to 10 hours) or delayed (48 to 96 hours) glycemia in pigeons (normal, hypophysectomized, or adrenalectomized) and rabbits; (*b*) ketonemia in rats, pigeons, and rabbits; (*c*) deposition of liver fat and glycogen in pigeons; and (*d*) effects on the

heat production and respiratory quotients of pigeons. In an intensive study of these related problems during the year Riddle and Opdyke have been variously aided by Bates, Miller, and Smith. Though parts of the data have not yet been analyzed completely, some of the significant results will be stated here.

Nature and actions of fractions from ammonium sulphate precipitation. Six fractions were obtained and each was studied both in fresh solution and as a dried powder. Four series of such preparations were made. In each case the starting point was, like that of Young, a pH 5.5 soluble fraction (little prolactin) obtained from an extract (pH 8.5) of fresh, quickly frozen beef pituitaries; this fraction, here called *A*, was used in this form for many tests. From an additional supply of this pH 5.5 soluble fraction five additional fractions (*B* to *F*) were prepared. The precipitate at one-third saturation with $(\text{NH}_4)_2\text{SO}_4$ provided on dialysis a soluble (*B*) and an insoluble (*C*) fraction. The precipitate next obtained from one-half saturation likewise provided on dialysis another pair of fractions, one soluble (*D*) and one insoluble (*E*). Finally, the protein which was precipitated at complete saturation and thereafter was soluble on dialysis ("albumen") was fraction *F*.

Fractions *A* and *D*, the "active" fractions of Young, contain measurable (and, in view of synergisms, probably non-negligible) quantities of gonadotrophin, thyrotrophin, adrenotrophin, prolactin, and posterior-lobe hormone; when freshly prepared they produce a ketonemia (10 hours after injection and 24-hour fast) which is considerable in rats, less in pigeons, and only slight in rabbits; stale and dried preparations lose ability to increase ketone bodies in the blood of pigeons; little loss was observed in rats. The two fractions are not equally potent in producing gly-

cemia in pigeons and rabbits, fraction *A* being more potent than any fraction derived from it. At 4 hours after injection of fresh fraction *A*, the blood sugar of 20 normal nonfasting pigeons was increased 45 per cent, and that of 6 hypophysectomized pigeons 41 per cent; the dry preparations were administered in somewhat larger doses and increased blood sugar by 37 per cent in 23 normal and by 31 per cent in 9 pituitaryless birds. All fractions, *A* to *F*, in both fresh and dried form, produce in nonfasting normal or hypophysectomized pigeons a glycemia at 4 hours after injection, and usually also at 10 hours in fasting birds (larger dosage with *C* and *F* was used to demonstrate this glycemic action); but daily injections of no fraction, in the dosage used by us, were able to produce a fasting hyperglycemia at the end of 4 days. Essentially the same results were obtained from New Zealand White rabbits. Especially at 10 hours the *F* fraction most consistently increased (30 to 52 per cent) the blood sugar of groups of rabbits. Toxicity of the fractions was indicated occasionally by fatal effects in both rabbits and pigeons. Fraction *A* ("diabetogenic" of Young) in particular, like some of our own "adrenotrophic" preparations, produces an early and temporary extreme glycemia—more than 100 per cent—in some (not all) normal and hypophysectomized pigeons, but we have demonstrated the still more significant fact that it does not increase the blood-sugar level of pigeons previously deprived of their adrenals.

It is notable that fractions *B*, *C*, *E*, and *F*, in either the fresh or the dried state, also increase (13 to 50 per cent) the blood sugar of groups of pigeons at 4 and 10 hours after injection; and here also this is not maintained to the third or fourth day. Again, most preparations of fractions *A*, *B*, *C*, and *E*, in the fresh and dried state, are notably ketogenic in rats, whereas dried *D* and *F*

are almost free of this action. The more immediate effect of these fractions on the liver glycogen is not yet adequately studied, but in normal pigeons injected for 3 or 4 days (24-hour fast), unmodified values (0.10 to 0.25 per cent) were obtained only with fraction *C*, the others giving values with a range of from 0.45 to 1.95 per cent.

A consideration of the action of these fractions on the liver fat—a subject which has been investigated more widely with the aid of preparations of purified hormones—may be given simultaneously with a statement of the results of our assays of the hormones contained in the several fractions, *A* to *F*. All preparations of fractions *A*, *B*, and *F* contained detectable amounts of posterior pituitary hormones. The latter were also present in two of the four preparations of fraction *C*, and probably smaller amounts in three of four preparations of *D*. Only in the four preparations of fraction *E* did our tests uniformly fail to detect posterior-lobe hormone. Prolactin was present in *A* fractions to the extent of <0.05–0.18 unit per mg.; it was concentrated (0.22–0.50 unit per mg.) only in the *C* fractions, leaving quantities smaller than that found in *A* in all other fractions (except *B*). It is significant that fractions *C*, *B*, and *A*, with the highest prolactin content, were the most potent in the production of fatty livers in pigeons (normal, hypophysectomized, or depancreatized). Fractions *D* and *F*, containing the least prolactin, apparently have the least action on liver fat. On the other hand, fraction *E* contained very little prolactin (and no posterior-lobe hormone detectable by our method), but in both the fresh and the dried state it was fairly potent in increasing liver fat. The gonadotrophin found in fraction *A* (0.06–0.32 unit per mg.) was usually most concentrated in fraction *D* (0.19–0.74 unit per mg.) and least concentrated in fraction *C* (0.02–0.22

unit per mg.). The amount of thyrotrophin in *A* (0.21–0.79 unit per mg.) was always increased in the individual preparations of fractions *B* (0.53–1.44 units per mg.), *D* (0.29–1.18 units per mg.), and in three of the four preparations of *E* (0.14–1.58 units per mg.); *F* fractions (0.12–0.17 unit per mg.) contained least thyrotrophin. Our assays for adrenotrophin were least satisfactory. All fractions stimulated the adrenals of 2-day chicks, but in no case were the four preparations of any fraction consistently high or low, and often there was poor agreement between adrenotrophin values found in the same preparation in the fresh and the dried condition. The data, however, provide no indication that high adrenotrophin values were associated with either glycemic, ketogenic, or liver-fat potency. In this connection it should be noted that our assays of adrenotrophin, made on 2-day chicks and on rats, wholly disagree when extracts of posterior-lobe tissue are subjected to assay by these two methods.

The care given to the assay of these several fractions for five different hormones has resulted in practical certainty that every fraction thus derived from ammonium sulphate precipitation contains four of these hormones in measurable and variable amounts, and that most of them also contain posterior-lobe hormone in addition.

In line with what would be expected from their thyrotrophin and prolactin content, all fractions—except *F*, which contains least of both those hormones—after 1 to 35 days of treatment increased the non-fasting respiratory metabolism of the young pigeons on which these various studies were made. This failure of the *F* fraction to increase heat production gains added significance from the fact that it, like other fractions, increased the blood sugar of normal pigeons at 4 hours (40 per cent, nonfasting) and 10 hours (30 per cent,

fasting) and of fasting rabbits (28 per cent) at 10 hours after injection. This indicates either (*a*) that thyrotrophin and prolactin are not primarily concerned in the causation of this quick and transitory glycemia in pigeons and rabbits, or (*b*) that one or the other of the two hormones must be present in larger amount or in a different proportion to induce such a glycemia, or (*c*) that the threshold for blood-sugar disturbance by these two hormones is lower than that required to increase the rate of heat production.

Combining tests made with the same fraction but after variable time and dosage, the following average heat-production values were obtained for normal birds: +30 (*A*), +12 (*B*), +77 (*C*), +1.3 (*D*), +41 (*E*), -12 (*F*). For small numbers of hypophysectomized birds these values were: +56 (*A*), +51 (*B*), +56 (*C*), +11 (*D*), +70 (*E*); no test was made with *F*. In general, it seems clear that these fractions increase heat production to a greater extent in hypophysectomized than in normal pigeons. Both fresh and dried preparations were thus active. The average of 47 determinations made with the fresh solutions on normal pigeons was +23.3; on 7 hypophysectomized, +43.8. In 47 tests on normal birds, dried preparations gave an average of +30.6; on 15 hypophysectomized, an average of +43.3.

Though it is evident that some hormone not assayed by us may be responsible for the experimental diabetes produced in certain other animals by fractions *A* and *D*, it is certain that the effective hormone (or hormones) was present in our *A* fraction, and it has been made evident that these fractions do not yield the full picture of such diabetes in the pigeons and rabbits used by us, though in some cases the tests were for 6 or more days. These birds, however, very temporarily yet very clearly show diabetic tendencies—glycemia, keto-

nemia, excess liver fat—after which the blood-sugar level is brought rapidly and completely under control. This control is likewise attained in birds deprived of their pituitaries, but, as in the cats and rats

doses of insulin on the processes of glycogenesis and lipogenesis in the livers of pigeons. Since pigeons withstand huge quantities of insulin, and their livers respond by growth to prolactin as to no other

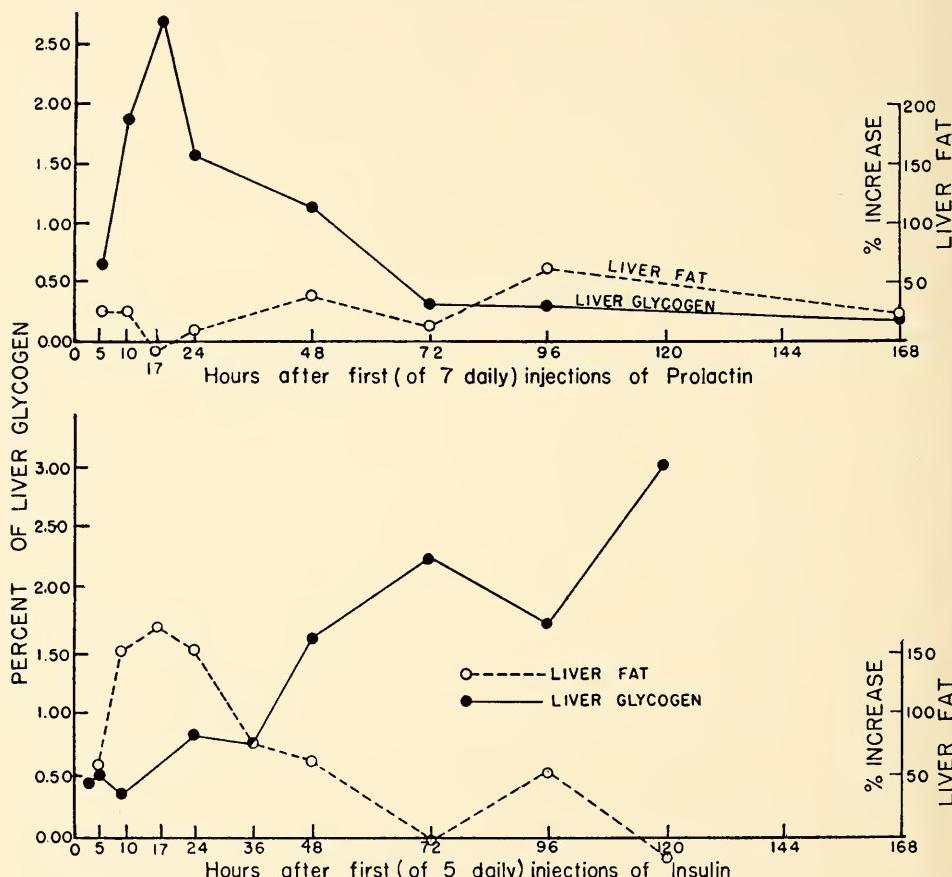


FIG. 2. Diagram showing the nature and extent of changes in liver glycogen and fat which follow the first and subsequent daily doses of 5 mg. prolactin or 30 units of insulin. The normal liver fat is taken as 100 per cent and increases are based on that value. All measurements were made on pigeons fasted 24 hours.

studied by Long and Lukens, a glyceremia is not produced in birds deprived of their adrenals.

Prolactin and insulin actions on liver glycogen and fat. Much interest attaches to results of a study by Riddle and Opdyke of the effects of prolactin and of high

hormone, these animals are exceptionally suited to this study. The results obtained are sketched in figure 2. All values shown were obtained in birds at the end of a 24-hour fast, and in birds injected once each 24 hours.

It will be observed that prolactin mod-

erately increases the liver fat at 5 and 10 hours, though apparently not at the end of 17 and 24 hours. Under daily dosage thereafter a variable but considerable percentage increase of fat (the original amount of fat considered as 100 per cent) occurs along with a doubling of the size of the liver itself. The most remarkable effect of prolactin, however, is its swift, powerful, and nonrepeatable effect on the storage of liver glycogen. By the fifth hour after a first injection of prolactin the liver glycogen has been slightly increased (to 0.66 per cent) and after 17 hours it reaches a very extraordinary value (2.66 per cent), which is clearly decreased at 24 hours (1.54 per cent). Despite the repeated daily injections of the same dose of prolactin, the glycogen further decreases at hours 48 (1.13 per cent), 72 (0.35 per cent), 96 (0.29 per cent), and 168 (0.18 per cent). Thus the first dosage swiftly piles up available carbohydrate in the liver, but soon thereafter other mechanisms of adjustment come strongly into action and these reinforced mechanisms can prevent a recurrence of this abnormal storage of glycogen during light fasting. It has been shown that when fasting is prolonged to 48 hours, and carbohydrate is less readily available, the same dose of prolactin after 10 hours will only slightly increase (to 0.53 per cent) the amount of liver glycogen. These data for glycogen were obtained from 83 pigeons of the same age and race.

Results of the parallel study made to determine the effects of insulin on the liver fat and glycogen of pigeons, and particularly the time relations for these two effects, are also shown in figure 2. It is notable that the *first* injection of insulin (30 units per bird) is followed by a swift temporary increase in liver fat, and that the curve which describes its changes is essentially parallel with the curve for glycogen (not fat) storage following a first injection of

prolactin. This action of insulin is also observed in hypophysectomized pigeons. Likewise a first heavy dose of insulin produces a marked ketonemia in pigeons, and this is not produced by dosage 2 days later. Initially, liver glycogen is unchanged or decreased by insulin, but we have observed a sharp temporary increase at 10 to 17 hours (not shown in the figure) and a durable extraordinary increase after 36 hours.

The "diabetogenic" actions of insulin. Insulin is much more than a cure for diabetes; the cure itself may be used to disrupt the regulation of carbohydrate and fat metabolism. Several years ago it was observed that pigeons tolerate huge doses of insulin and that, in some birds thus treated, the short period of very low blood sugar might be followed by a great excess of blood sugar. Extreme glycemas (increase of more than 100 per cent) have now been shown by Riddle and Opdyke to be the usual result of two, three, or four daily injections of pigeons with huge doses (30 units) of insulin. These glycemas persist during only a few days following a last injection, but in this they equal or excel any glycemas we have observed following the use of pituitary extracts. Again, a marked ketonemia results from the first of such insulin injections (10 hours after injection, 24 hours fast) at a time when the blood sugar is still somewhat reduced by the heavy dosage; after three daily doses, however, when a marked glycemia is present, no ketosis occurs. A similar ketonemia is obtained in rats. The extent to which injections of 30 units of insulin into normal pigeons result in an increase of both liver glycogen and liver fat has been noted in the preceding paragraphs. In hypophysectomized pigeons extreme fatty livers (3.66 times normal) are produced during the first 24 hours, and thereafter this action is progressively diminished; however, in such birds an increase of liver glycogen has been

found at no time between 10 and 120 hours.

Thus in normal pigeons four important changes in the metabolism of carbohydrates and fat—changes which are commonly described as results of administration of anterior pituitary substance—have now been observed to result also from high dosage with insulin.

Hormones which increase liver fat. Still other studies conducted during the past three years have sought to learn the action or lack of action of the various hormones on liver fat as this action may be detected in pigeons and rats. These studies by Riddle, Oddyke, and Senum are still in progress. Comparable results have not always been obtained in the two species chosen for study, and it is still uncertain whether apparent differences are real or whether only time relations and degree of response are different. It has been satisfactorily demonstrated that in pigeons liver fat is increased by estrone, desoxycorticosterone, and insulin; also to an irregular extent by prolactin, and consistently by some pituitary hormone or mixture of hormones other than purified prolactin, adrenotrophin, gonadotrophin, or thyrotrophin. Like Campbell and Keenan we find that liver-fat activity of pituitary extracts is separable from ketogenic activity, but unlike those authors we have been able to concentrate (though not completely to separate) liver-fat activity from a suitable pituitary extract by precipitation at one-third saturation of ammonium sulphate.

The results of the several studies described above seem to make it probable that no single pituitary hormone is responsible for either ketogenic, strongly glycemic (diabetogenic), or excess liver-fat activity. These results are in better accord with the view that normal regulation of carbohydrate and fat metabolism is more seriously deranged when two or

more participating hormones are present in unusual or in unfavorable concentration and exert their stimuli simultaneously. Intensification of the activity of a single hormone is probably less disruptive to a very generalized and many-sided process than is intensification of contradictory activities in two or more organ systems. There is little or no valid evidence for the existence of an extra or otherwise unrecognized pituitary hormone with specific action on the metabolism of either carbohydrate or fat.

This study of carbohydrate and fat metabolism was aided by a grant from the Committee on Research in Endocrinology, National Research Council. Much technical assistance in these and other studies was given by Mr. Louis Stillwell, Jr.

SEASONAL AND CYTOLOGICAL ENDOCRINE CHANGES

Cyclical response in viscera. It was noted last year that at two periods of the year, namely April-May and October-November, the crop sacs of pigeons give an especially low response to prolactin. Other data obtained by Bates and Riddle in connection with that study have now been summarized. The 239 White Carneau pigeons thus examined at short intervals over a period of two years were all sacrificed at the age of 7 weeks. Their body weight showed an annual variation, with a maximum in winter and a minimum in late summer. Weights of heart and adrenals showed no obvious cyclical or seasonal change. Length and weight of intestine at this age were found to be independent of body weight and essentially constant throughout the year. If these values are corrected to constant body weight, they would therefore seem to show annual cycles which are reciprocally related to body weight. When weights of pancreas

and liver are calculated to constant body weight, they, however, tend to show a semiannual cyclic variation similar to that found, with or without that calculation, in the crop sacs. The similarity of this seasonal variation in the response of pancreas, liver, and crop sacs to prolactin may therefore be regarded as still another indication that prolactin is associated with the growth or functioning of these three organs. On this view, however, one would expect the intestine to fluctuate similarly; actually, in these data intestinal length and weight show neither semiannual variations in response to prolactin nor dependence on body weight.

A stepwise change in thyroids. Though seasonal changes in thyroid weights of pigeons were reported from this laboratory nearly twenty years ago, and though the establishment of races of doves and pigeons characterized by hereditarily large and small thyroid size was reported five years later, the remarkable changes described below are notable despite the fact that they are not yet understood. Incidentally to making numerous assays of pituitary hormones during the past several years, the thyroid weights of large numbers of untreated (control) pigeons have been obtained by Bates, Riddle, and Lahr. White Carneau pigeons aged 6 weeks were obtained from the same commercial hatchery (Palmetto Pigeon Plant, Sumter, South Carolina) over a period of five and a half years, and thyroid weights from 862 such birds were obtained 7 to 10 days later. During the first two years of observation the average weight of the thyroids was uniformly close to 40 mg. Successive lots of birds received in the autumns of 1938, 1939, and 1940 showed a stepwise increase in thyroid without subsequent complete return to previous summer levels. Early in 1941 an average weight of 179 mg. was

attained, and in the summer of 1941 the average was reduced to 60 mg.

The source or cause of these changes is largely unknown, but a combination of hereditary and environmental factors is suspected. The nature of the changes has received some attention. Incomplete histological data indicate that the later and larger thyroids of these young birds were functionally more active. A few old birds in the parent colony have been found recently to have extremely large thyroids, 13 to 14 g., which histologically seem practically inactive. Ninety-one determinations of the basal metabolic rate made by Smith and Riddle on young birds before and after the period of thyroid enlargement indicate an increase of only 5.5 per cent in the group having larger thyroids; eight such measurements made in 1941 on 2 adult goitrous pigeons from the same colony gave basal values 3 to 28 per cent below normal, but with indications that the nonfasting heat production is normal. During the past three years the thyroids of this widely used strain or type of pigeon have been wholly unsuitable for the bioassay of thyrotrophin, though they earlier gave clear evidence of suitability.

Cytological changes in adrenals. We have reported earlier on certain relations between the cytology of the pigeon's adrenal and its physiological activity. In experiments with insulin, continued from last year, Miller and Riddle find that as early as 10 hours after injection cytological changes become apparent in the cortex which are similar to those induced by adrenotrophin, and this stimulation has now been observed in the adrenals of hypophysectomized pigeons. Mitoses and cytological changes observed in medullary cells supply morphological evidence that these cells also are stimulated by insulin. These data apparently provide an explanation for re-

lated observations made in this laboratory. As noted elsewhere, Riddle and Opdyke find that large doses of insulin repeatedly injected into pigeons rapidly lose their ability to depress the blood sugar and indeed soon produce marked hyperglycemias. These facts suggest that both cortical and medullary portions of the adrenal gland actively oppose the hypoglycemic action of insulin. Recent tests have shown that adrenalectomized pigeons cannot tolerate large doses. The notable, and apparently unusual, ability of the pigeon's adrenal gland to respond to insulin may therefore provide an explanation for the resistance of these birds to doses of insulin which would quickly kill a mammal.

PITUITARY AND BLOOD STRUCTURES

The endocrine control of hemoglobin regeneration and the maintenance of normal distribution of leucocyte types in the blood has been the subject of preliminary investigations by Wells, Miller, and Riddle. Normal and hypophysectomized pigeons have been rendered anemic by bleeding and the hemoglobin concentration observed at intervals of three or four days. In the first of our studies it appeared that nutritional factors were obscuring the influence of the pituitary. To minimize such factors, all subsequent experiments have been conducted upon animals force-fed on 15 g. grain daily. It is found that hypophysectomized pigeons receiving large daily injections of whole anterior pituitary extract show a distinctly lower rate of hemoglobin replacement than do similarly operated animals when left untreated. It is suggested that the normal balance between hemoglobin formation and hemoglobin destruction is subject to pituitary control, but the final validity of this inference must rest on careful exploration of such factors as total blood volume, adequate supply of

iron and protein, integrity of hematopoietic tissue in operated animals, etc. Our finding of lower hemoglobin values in birds treated with pituitary extract, and with prolactin, seems paradoxical, but it is in accord with observations made by Querido and Overbeek, who have reported that in rats the mechanism of blood destruction is activated by a pituitary product.

Blood smears from the ringdoves and Carneau pigeons have been studied and the percentage occurrence of the different leucocyte types has been tabulated. We have found it possible to recognize the following distinct forms of white cells: *A*, lymphocytes, small, medium, large; *B*, eosinophiles with rods; *C*, eosinophiles with granules; *D*, basophiles. The distribution of white-cell forms in the blood of pigeons is found so strikingly inconstant that conclusions based on apparent changes in relative occurrence would need the support of inconveniently large numbers of observations. It therefore becomes desirable to search for the factors responsible for the wide variations observed in normal birds and thus determine whether a particular distribution of cells is characteristic of an individual animal or is subject to periodic change. At this time we can only suggest that sex factors play some part in this connection. The male pigeon appears to have a higher percentage of eosinophiles with rods than does the female. A sex difference of this type has been noted by other workers in the leucocytes of chickens.

HORMONES AND REPRODUCTION

In doves and pigeons the ovum breaks out of its enclosing membranes in the ovary—that is, it ovulates—at a fixed and known hour in the evening. Using this fact, Drs. Dunham and Riddle have studied the ability of several sterol hormones to

hasten, delay, or otherwise affect the process of ovulation in these birds. A single injection of the hormone was made at times varying from 5 to 34 hours before the normal hour for ovulation. From 23 tests of the action of the corpus luteum hormone, progesterone, and from 43 tests of desoxycorticosterone acetate (a synthetic product resembling hormones of the adrenal cortex), it was found that doses of only 0.1 and 0.05 mg. of these substances prevent normal ovulation. Both substances cause the egg membrane and the inner walls of the follicle to break at various places and thus permit the flow of yolk fragments into spaces formed within the follicular wall. Thereafter, the external walls of one or more of these spaces may break and permit the release of more or less yolk into the body cavity. These two substances also decreased the amount of shell which was placed on eggs ovulated prior to injection; the time during which such eggs remained in the shell gland was, however, not diminished. Considerably higher doses of androsterone (6 tests), dehydroandrosterone (42 tests), and estradiol benzoate (102 tests) sometimes produced similar effects on ovulation but had no detectable effect on shell formation. Estradiol benzoate showed a peculiar action in that in 26 of the 102 tests it caused a 24-hour delay in ovulation.

Other investigators have noted earlier that progesterone and testosterone will induce ovulation in certain toads (*Xenopus*) and frogs; and in some mammals hitherto tested the results resemble those observed here in birds. The mammalian studies have been thought to indicate that these sterols exert their action not on the ovary itself, but through suppression of output of gonadotrophin by the pituitary. The present results may be similarly interpreted. This is the more probable in the cases of progesterone and desoxycorticosterone, since studies reported below by Lahr and

Riddle show that these substances cause a rapid and extensive atrophy of the testes of adult ringdoves.

In 1937 this laboratory reported that a commercial preparation of testosterone, Erucon, like prolactin, estrone, and progesterone, exercised an anti-gonad action on the testes of adult doves and pigeons. During the past year Lahr and Riddle have made further tests with crystalline hormones which confirm the earlier report for all the above-named hormones except testosterone, and the newer study further adds desoxycorticosterone acetate to the list of anti-gonad sterols. Four series of tests made with pure testosterone or its propionate, at various levels of dosage, have shown little or no anti-gonad action. Three series of tests with crystalline androsterone have all indicated that this hormone tends to increase the weight of the adult bird testis.

HORMONAL MODIFICATION OF SEX

Several years ago Riddle observed the presence of left oviducts in some male doves, and also certain elements of accentuated femaleness in female doves, which were hatched from eggs that matured in rapid succession ("crowded reproduction"). Somewhat later these effects were interpreted as actions of the increased amounts of estrogen which eggs (yolks) formed in rapid succession would probably contain. Others meanwhile have shown that the injection of estrogens into the albumen of eggs of fowl during early stages of incubation is followed by the development of left oviducts and also of ovarian tissue on the testes in genetically normal males. During the past year Dunham and Riddle have subjected Riddle's view to test. This was done by injecting estrogen into female doves at a time when they had in their ovary an ovum (yolk) which would con-

tinue its rapid growth for 26 to 34 hours before breaking from the ovary; thereafter these eggs were hatched, and the young were kept alive for periods varying from 1 day to 9 months, and then sacrificed to observe any modification of the sexual apparatus of male offspring. The tests were limited to the more easily measured changes induced in males.

Only a single injection of 1.0 or 0.5 mg. estradiol benzoate (or of dehydroandrosterone) was given, and this always at 26 to 34 hours before the second ovum of the dove's clutch of two eggs was to be ovulated. During that time the mother bird had opportunity to put portions of the added estradiol into the growing (second) yolk and perhaps later, after ovulation, to put more into the albumen which must form before the egg is laid. It should be noted also that the first egg of the clutch, though already in the oviduct at the time of injection, might have opportunity to take up small amounts of the injected estradiol into its albumen but not into its yolk. Quite in correspondence with the difference in the opportunity for the passage of estradiol into the two types of eggs, the males obtained from "first" eggs showed slight but perhaps significant effects in only 3 of 10 tests, whereas "second" eggs from the highest dosage (1 mg.) all showed (5 cases) significant effects, as did also at least 7 of the 12 cases derived from the lowest dosage (0.5 mg.). Thirty-one males from untreated eggs served as controls.

Effects were observable either in the oviducts or in the left testes, or in both oviduct and testis, in the test males killed at various ages from hatching to 7.6 months. One male at 9.2 months, from treatment with 0.5 mg. estradiol, seemed then to show no effect of the treatment. The left (sometimes also the right) oviducts often showed some degree of per-

sistence, and in several instances oviductal remnants were wholly included in the walls of one or more distended, fluid-filled vesicles; these Müllerian vesicles were wholly characteristic of the treated males and were never found in the controls. In connection with this study we have found that the newly hatched dove, like the sparrow (Witschi) and robin (Unger), normally shows small amounts of ovarian cortical tissue on the left testis, and that this completely disappears within a few days after hatching. A significant effect of the estrogenic hormone on this tissue consisted in extending, both in space and in time, the development of this normal fragment of ovarian tissue in the left testis. Such tissue was not observed in the right testis in any case. It has thus been demonstrated that a female dove may herself pass estrogen from her blood into her maturing eggs, and that males hatched from eggs which receive an unusual amount of such estrogen may show, at least for some weeks or months, developmental effects of that hormone by possessing oviducts or by the persistence of ovarian tissue in their left testis. This new information clearly suggests that the small amount of ovarian tissue (bisexuality) often or usually present on the left testis of the bird embryo is itself the result of estrogen passed by the mother into her maturing eggs.

GENETIC HERMAPHRODITISM IN PIGEONS

The occurrence of genetically determined hermaphroditism in one strain of pigeons in our colony has been reported earlier. The breeding of this strain is of course being continued. During the past year some special study has been made by Riddle and Dunham of hermaphrodite and pseudohermaphrodite offspring of this

strain of birds. Originally a true hermaphrodite was found which proved to be capable of very limited breeding if used as a male. A normal sister of this hermaphrodite, when outcrossed to a male of another race, produced (first generation) one true hermaphrodite which, when bred as a male to a sister, threw 7 true hermaphrodites (second generation). Further breeding is already known to have yielded 3 true hermaphrodites in the third and 3 in the fourth generation. Offspring in all generations are of the following types: normal females, normal males, males with left oviducts, and males (true hermaphrodites) with ovotestis and oviduct on the left side and a testis on the right side. The ovotestes have been found in birds whose

ages varied between hatching and 75 months. Biopsy proved the persistence of an ovotestis for more than 40 months. Of special interest is a considerable proportion of males having a left oviduct and two testes without tissue identifiable as ovarian; there is, however, some probability that such tissue was present at an earlier stage of the bird's life. Oviducts have been observed to attain a weight of 1.9 g., which is about double that of the oviduct of a normal female not actively producing eggs. Such development of oviducts in birds otherwise apparently male indicates that these birds are producing large amounts of estrogenic hormone and thus, on the basis of their internal secretions, their gonads also are partly female and bisexual.

MOUSE GENETICS

E. C. MACDOWELL, J. S. POTTER, M. J. TAYLOR, E. N. WARD, AND T. LAANES

SPONTANEOUS LEUKEMIA

In the investigation of the complex interactions of intrinsic and extrinsic influences on the incidence of spontaneous leukemia in mice, a second backcross experiment has been described (Year Book No. 39, 1939-1940), which was designed to determine whether or not the transmitted tendency leading to the spontaneous occurrence of leukemia is subject to Mendelian segregation—that is, under the control of genes in chromosomes. In this experiment the classification of 50 males in the first backcross to the low-leukemia strain was based on the incidence of leukemia among their respective progenies (total 2677 autopsies) in the second backcross to the low-leukemia strain. During the past year the histological diagnoses of these mice have been completed and extensive studies made of the data, which cover 14 criteria for each mouse. The final classifications confirm the preliminary conclusion that no single

gene plays an outstanding part and, further, provide evidence of segregation in that the first-backcross animals show genetic diversity in regard to the appearance of leukemia. More than this, indications have been found of the nature of part of this genetic influence and of an important nongenetic influence.

The elementary analysis of these data by means of averages, subclassifications, frequency distributions, scatter diagrams, and other graphic arrangements indicated various heterogeneities and correlations within as well as among the various progenies, but the evaluation of the relative importance of these interrelations and the search for all possible clues to any sort of factor influencing leukemia required far more complex and laborious statistical analyses. This laboratory could provide neither the experience nor the technical facilities to carry out such an analysis with such large numbers. Very fortunately, Professor John

W. Gowen, of Iowa State College, while spending a few weeks here last fall as guest of the Department, became acquainted with these data. His interest in the general problem, as well as his long experience in dealing with parallel statistical analyses, and the organization of statistical machinery and calculators at his disposal, prompted his extremely generous offer to carry through the necessary analyses of these data. Accordingly all the data were coded, sent to Ames, Iowa, and there transferred to punched cards. Though the work has not been completed, certain important results have come to light.

The two inbred strains used in the cross differ in three pairs of genes for color, so that eight color classes appear in the second backcross. Each gene appears in four combinations with the others. The gene for dark eyes shows higher percentages of leukemia than does its mate for pink eyes in three of the four corresponding combinations, but the amounts of these differences do not reach statistical significance, since, with 1 degree of freedom, the X^2 is 0.9 with a probability (P) of 0.40. The gene for black, however (originating in the high-leukemia strain), gives higher percentages for leukemia than does its mate, the gene for brown, in each of the four corresponding combinations, and the gene for dilution (originating in the low-leukemia strain) gives higher percentages for leukemia than does its mate for intensity in each of the four corresponding combinations. These differences are significant since the respective X^2 are 8.9 and 11.6, which, with 1 degree of freedom, indicate probabilities of less than 0.001. In the analysis of the total variance of leukemia, however, the influence of each of these genes in determining whether or not a mouse dies of leukemia is found to

be relatively small, in the neighborhood of 4 and 5 per cent.

In the original cross between these high- and low-leukemia strains, the first-generation hybrids with mothers from the high strain gave higher incidence of leukemia than those whose fathers came from the high strain. To observe genetic influences unconfused by such possible maternal influence, the mothers in each generation of the present experiment were taken from the purebred low-leukemia strain; that is, the only ancestor from the inbred high-leukemia strain was the great-grandfather of the mice under consideration. In order to produce the entire second-backcross generation in a short period of time, more than half were nursed by foster mothers from our albino strain, because these mice are exceptionally good nurses. No consideration was given to a possible influence of this foster nursing, for the appearance of leukemia in this strain is rare, as it is in the low-leukemia strain (StoLi) used in the cross. The totals, however, show a higher incidence of leukemia among those nursed by the albino-strain nurses (19.6 per cent) than among those nursed by the StoLi nurses (12.3 per cent). Within 34 of the 50 families the percentage of leukemia is higher for the albino-nursed young; in 12 families it is lower, in 3 it is equal, and in 1 family all the mice were raised by albino nurses. The albino-nursed young gave no leukemia in one family, and the StoLi-nursed young gave no leukemia in 10 families. That this difference is real is indicated by the X^2 of 24.1 with 1 degree of freedom, giving P less than 0.001. Since each family was not divided equally between nurses from the two strains, it is important to see how much the heterogeneity in the distribution of leukemia among the families of the different backcross sires is influenced by the

nurse. Counting only the young nursed by StoLi mice, the X^2 of 72.8 with 49 degrees of freedom gives a probability of 0.015; counting only the albino-nursed young, the X^2 of 134.7 with 49 degrees of freedom gives a probability of 0.00001. Thus the sires are shown to be heterogeneous in their ability to transmit leukemia whichever strain of nurse is used, but the significance of this heterogeneity is considerably greater when the albino-nursed young are considered. In the analysis of variance the F value (12.6) for effect of nurse is highly significant, and in the estimate of proportionate influence the contribution of the nurse seems to be about 20 per cent. Here, then, are different results from nurses from two strains in each of which leukemia is rare. An influence must be sought that is transmitted by nursing and yet ineffective in the animals providing such influence.

With this result in mind, the records of the original first-generation hybrids were retabulated according to the strain of the nurse. When the mother came from the high-leukemia strain the totals showed 61.9 per cent leukemia; when the father came from the high-leukemia strain the total showed 42.5 per cent leukemia. But when these reciprocal hybrids were raised by albino nurses the difference in percentage of leukemia vanished (51.3 and 52.1 per cent). Further, when the hybrids with high-leukemia fathers were raised by StoLi nurses the leukemia was reduced to 35 per cent. This is a greater difference between albino and StoLi nurses than was observed in the second backcross, but it is in the same direction and serves to confirm the result reported above. Hybrids from high-leukemia mothers were also raised by high-leukemia nurses, with a rise in the leukemia to 73.8 per cent. Thus the albino nurses have a more potent influence on the incidence of leukemia than do StoLi nurses,

but nurses from the high-leukemia strain have a still more potent influence than the albinos. It appears that the effort to avoid the question of the influence of nursing has resulted in finding strong evidence of its effectiveness in influencing the incidence of spontaneous leukemia in our mice.

Dr. Gowen's analysis has brought out most impressively the influence of age factors. In the analysis of variance of leukemia, age stands out with higher significance than any other known effective variable ($F\ 22.0$ with degrees of freedom 1 and 18) and seems to contribute about 51 per cent of the total variance. That the sires differ genetically in their influence on the duration of life of their respective progenies is shown by the highly significant age differences. The ratio of the mean square of ages within families (degrees of freedom 2627) and between families (degrees of freedom 49) is $F=32$. Thus, from the point of view of what it is in the inheritance that contributes to the expression of leukemia, the major item appears to be the genetic constitution for duration of life passed on to the second-backcross progenies by their respective sires. But this is not the only effect of the inheritance, for after the duration-of-life effect has been taken out by corrections based on a life-expectancy table constructed from the massed data, there still remain other, as yet unknown, inherited characters which contribute to the appearance of leukemia and become especially effective when the mice are nursed by albinos.

MITOCHONDRIA IN LEUKEMIC CELLS

Numerous investigators have estimated roughly that the mitochondria in individual malignant cells, as compared with normal, are increased in number and decreased in size. As a part of our cytological survey of leukemic cells, the mitochondria in

populations of lymphocytes of spontaneous leukemia, of transplantable leukemia, and of normal animals have been counted. Two observers independently made these counts in random samples of supravitally stained cells on each of ten slides from each source: 1000 cells from each of four lines of transplantable leukemia, 1000 cells from spontaneous leukemia, and 2000 normal cells. The frequency distributions of the counts were characteristically different, with statistically significant differences between the means. The mean number of mitochondria for a population of normal lymphocytes was found to be 21.57 ± 0.21 , S.D. 6.95 ± 0.15 ; for a population from spontaneous leukemia, 27.93 ± 0.26 , S.D. 8.40 ± 0.15 ; and for a population from a transplantable leukemia, 32.47 ± 0.28 , S.D. 8.95 ± 0.20 . In general, the greater the virulence of the population, the more numerous the mitochondria, but instead of a reduction in size, the increase in number is accompanied by an unquestionable increase in size.

These various populations, however, besides differing in malignant properties, have been shown to differ also in the proportions of cells in the various stages of differentiation. When the number of mitochondria was correlated with the degree of differentiation, it was found that the amount of mitochondrial material increased with the immaturity and the physiological activity of the cells, and that cells of the same degree of differentiation from all populations, whether normal or highly malignant, showed no difference in mitochondria. This cell characteristic therefore does not offer a specific criterion of malignancy.

ANALYSIS OF LEUKEMIC CELLS

Through the cooperation of Dr. Albert Claude, of the Rockefeller Institute for

Medical Research, we have been able to gain information concerning the chemical and physical nature of certain fractions of leukemic tissues.

Dr. Claude has continued his study, mentioned in last year's report, of a fraction of leukemic tissues isolated by means of differential centrifugation. We have made further tests of its antigenic activity. This purified fraction is obtained after repeated high-speed centrifugation, and is composed of small particles which may be suspended in neutral media but will agglutinate in acid media. Microscopically, the variation in size among the granules is not great, and they may be stained with acid dyes when air-dried films are prepared. Dr. Claude has stated in published reports on similar fractions from other tissues that the particle size and proportion of phospholipids and proteins suggest that mitochondrial material is included.

Two sets of animals were injected with this material and tested for immunity reactions. The test dose of leukemic cells was given 10 days after the single injection in the first experiment and 10 days after the third injection in the second experiment. Transplantable line I leukemia was used for the production of the high-speed sediment and also for the test dose. For results see first table on page 249.

Dr. Claude has analyzed chemically the high-speed fraction obtained from two of our transmission lines, one of moderate virulence, line S, and one of high virulence, line I. The high degree of accuracy of the methods makes certain of the differences seem significant. See second table (p. 249).

SCREW TAIL MUTATION

In mice the appearance of a mutation with little variability in somatic expression and in ratios is so rare that special mention is merited. In the present case

interest is attached to the demonstration of simple Mendelian segregation in a highly inbred strain without the conventional outcross. Indeed, the uniformity of the genotypic background after 50 generations of brother-by-sister matings may well be responsible for the value of the mutation and its excellence as a tool for the analy-

this appears as a deficiency of 5 per cent in the natal sex ratios and as a reduction from the expected 25 per cent of screw tails to 21.1 per cent (of 649 mice) in matings between heterozygous normal parents. In the same matings 24.7 per cent of the 704 females were screw tail. Thus, however early the gene may start its activities, the

ANTIGENIC EFFECTS OF HIGH-SPEED SEDIMENT FROM LINE I LEUKEMIA IN STRAIN C58 MICE

	No. mice	No. died	No. survived	Average interval before death (days)	Per cent survived
Experiment 1:					
Sediment, 1 injection.....	20	19	1	7.26	5
Controls.....	20	20	0	6.83	0
Experiment 2:					
Sediment, 3 injections.....	20	13	7	6.88	35
Controls.....	19	19	0	6.72	0

LEUKEMIA IN MICE (STRAIN C58): CHEMICAL COMPOSITION (IN PERCENTAGES) OF THE "SMALL PARTICLES" ISOLATED BY DIFFERENTIAL CENTRIFUGATION

Element	Line I	Line S
Nitrogen.....	8.30	8.38
Phosphorus.....	0.97	1.31
Carbon.....	52.55	53.10
Hydrogen.....	8.00	8.57
Ash.....	10.75	9.10
Sulphur.....	0.91	1.46
Copper.....	0.023	0.017
Amount purified fraction in spleen (dry weights).....	10.1	10.8

sis of developmental processes. However simple the segregation, the effects of the screw-tail gene are far reaching. The tightly coiled tail gives an easy identification of the homozygous screw-tail animals at birth, but besides this, the gene so modifies growth and development that more than two-thirds die within the first four weeks and fertility is exceedingly low. Before birth there is some loss of males;

serious handicaps appear largely after birth, so that the first steps of the study of the developmental physiology may be made with living animals. Indeed, the first problem arises immediately after birth in the consistent failure of the screw tails to fill their stomachs, even with competition removed and without any evidence of maternal discrimination.

Ratios of 3:1 are insufficient to prove genetic segregation, especially when the progenies are selected by the presence of mutants instead of being defined by the experimental procedure. This is the difficulty in interpreting human pedigrees. Accordingly, breeding tests to determine the ratio of heterozygous and homozygous normals become especially important. Of 59 normal females, sibs of screw tails, tested by matings with known heterozygous males, 20 were found to be homozygous normal and 39 heterozygous (expected 19 2/3: 39 1/3). Similar tests of 18 normal females from matings between homozygous and heterozygous normals showed that 7

were homozygous and 11 heterozygous (expected 9:9). In spite of the exceedingly low fertility of screw tails, a few litters

obtained from screw tails and heterozygous normals included 15 screw tails and 14 normals.

ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND HENRI C. SEIBERT

ANTHROPOLOGY

Corn production in Yucatán. The author's experimental cornfield near Chichen Itzá is now in its eighth year of production. The records of yield and cost of production are published elsewhere, but mention should be made that it is becoming increasingly difficult to raise corn on this plot. At present, weeds and the encroachment of grass, in spite of careful hand weeding, seem to make it impossible to grow corn for any considerable length of time in the Maya fashion at a profit. It is the author's belief that within a few years the weeds and grass will have become so firmly established that no corn can be grown at all on this field. Another factor which probably hinders the growth of corn in Yucatán after continuous production is that the soil is only a few inches deep. Thus, we have shown experimentally possible reasons why the ancient Maya were apparently seldom able to remain in a given locality for a long time before being forced to move to a new location; for if the population increased to such an extent that land was at a premium and old fields could not be left long enough for forest to grow back, thoroughly shade out the weeds and grass, and give the soil a chance to build up, a shift would have to be made to a less crowded area.

Human pedigree studies. This year the senior author has concluded ten consecutive seasons of work in the village of Piste, Yucatán. One project in this village concerned a study of the families and their

relatives. The author has now finally checked and has on record complete pedigrees of the four major families in Piste, namely, Ceme, Dzib, Tun, and Mex, as well as one chart covering the families of May, Mis, Ek, Cauich, and others. These pedigrees record the names and relationships of more than a thousand persons, showing which individuals have been measured and described. They have produced data on the demography of the community and are serving in the analyses of hereditary traits which occur in these families; and they will be guides to geneticists and historians who wish to trace family relationships in future studies on the primitive Indians of Yucatán. The pedigrees will be available for future investigations.

ANTHROPOMETRY

Indians of South America. Considerable time has been spent this year in reviewing the literature on the anthropometry of South American Indians. This was done in connection with a proposed handbook on South American Indians being prepared by the U. S. Bureau of American Ethnology. Our part in this handbook concerns the anthropometry of the living tribes. To date we have reviewed anthropometric data on more than one hundred tribes, including their exact location and linguistic affinities. Charts and maps are being prepared to show the average statures and cephalic indices as well as other body proportions for all tribes which have been scientifically measured.

Growth of children of different races. Each year more data are gathered on the growth of children of four racial groups: Maya and Navajo Indians, Negroes, and Dutch whites. Individual children of these races are measured annually and their growth plotted and recorded. The Maya children measured first in 1931 are now fully grown and for the most part have children of their own. They were measured for the last time this year. The children of the other races are in their ninth and tenth years of measurement and many of them are still growing and attending high schools and colleges. Perhaps the most interesting facts learned this year from the growth data pertained to the eruption time of teeth. We can now say definitely that the order in which teeth appear in the mouth is essentially the same for the four races considered. That order is as follows: first molar, central incisor, lateral incisor, first premolar, canine, second premolar, and then second and third molars. This order has been known for the white race, but it was not known or clearly demonstrated that the Maya Indians of Yucatán and the Navajos of Arizona followed the same pattern. There are, however, significant racial differences in the average age of individuals at the time of eruption of the teeth. Thus, the Navajo have the earliest eruption time of all the races studied, and the Negroes also erupt their teeth consistently earlier than the whites. The Maya erupt all teeth except the central incisors at an earlier time than do the whites.

Female/male index. One hundred Negro males from Tuskegee Institute were measured this year for a comparison with the 100 Negro females measured last year. Each of the 50 dimensions taken on this college group is considered in a ratio, showing the percentage which the female measurement is of the male measure-

ment. Thus, the weight of Negro females averages about 80 per cent of that of Negro males. Such ratios are compared with those derived from the author's previous work on Jamaica Negroes and Dutch whites. The major results of this study are summarized briefly as follows: In stature, the sexes are more alike than they are in weight, having an index of 93.4 per cent. This figure is practically identical with those obtained by the author for other races. For example, Dutch white males and females from Holland, Michigan have a female/male index for stature of 93.5 per cent; Jamaica blacks, browns, and whites have indices of 92.8, 93.3, and 92.9, respectively. In all the measurements considered, the ratios are less than 100. When, however, body indices, composed of a ratio of two body measurements, are considered in female/male ratio, there are many in which the females exceed the males. For example, for the index intercristal breadth divided by biacromial breadth (pelvis width by shoulder width), the female/male ratio is 1.058 for Negroes and 1.145 for Dutch whites. This trunk index shows a marked sexual dimorphism. The index for males averaged 70.64 ± 0.25 and the females 74.76 ± 0.27 , a difference which is highly significant, being 11 times its probable error. The Dutch white ratio is higher than the Negro, possibly owing to an age difference in the individuals measured from the two races. The corresponding female/male ratios for trunk index for Jamaica blacks, browns, and whites are 1.102, 1.075, and 1.053, respectively. Similarly in the study of sex ratio each of 50 other dimensions is considered.

A STATISTICAL STUDY OF HUMAN HEAD HAIR

We commonly speak of a "hair's breadth," meaning a very small unit of

measure. A recent advertisement in a scientific journal speaks of "1/5 the width of a human hair." Such statements scientifically mean very little, for studies on human hair show that hairs from different parts of the body differ widely in their diameters. Our studies show that races differ widely in the widths of their head hair, this variation ranging from 10 microns to 200. Similarly the variation in size of hairs of one individual is known to be very great. For example, one Maya Indian had head hairs which varied in maximum diameter from 25 to 120 mi-

continue with this analysis of hair "widths" and also with a more general study of hair color.

For last year's report, the area of the cross section was determined with a planimeter and recorded in such units. The means for each dimension were obtained from a relatively small number of cases, with an unequal number of males and females in each distribution. During the year we were able to section hairs from two more racial groups, and for each of the six races a mean was determined based on five males and five females of

MEANS WITH PROBABLE ERRORS FOR CROSS SECTIONS OF HEAD HAIRS FROM 10 INDIVIDUALS
(5 MALE, 5 FEMALE) FROM EACH OF SIX RACIAL GROUPS

Race	No. hairs	Area ($\mu^2/100$)	Maximum diameter (μ)	Minimum diameter (μ)	Index
Maya.....	986	41.05±0.29	79.53±0.34	64.90±0.24	82.94±0.24
Hopi.....	617	45.08±0.50	83.70±0.56	65.31±0.35	80.89±0.36
Navajo.....	1002	40.65±0.38	78.76±0.41	61.96±0.28	79.73±0.27
Zuñi.....	643	43.37±0.49	84.33±0.58	62.81±0.33	77.19±0.36
Dutch.....	858	24.11±0.24	63.93±0.37	47.28±0.22	75.99±0.31
Negro.....	873	40.06±0.35	90.62±0.47	51.70±0.27	57.40±0.26

crons, and in a Negro the range was even greater, namely, from 20 to 130 microns.

Hairs rarely are true cylinders, but are more like an elongated ellipse in cross section and consequently have a maximum and minimum diameter. The greatest difference between maximum and minimum diameter is among Negroes; some Negro hairs may have a minimum diameter of 50 microns and a maximum of 100.

In last year's report preliminary data were given showing racial differences in area, maximum and minimum diameters, and index of cross sections of human hair. In that report we described the technique whereby 100 or more hairs may be sectioned in as little as 10 minutes, as compared with two or three days with the older technique. In this report we shall

approximately the same age. Likewise it was determined that the formula

$$A = \left(\frac{D_1 + D_2}{4} \right)^2 \times \pi$$

was as accurate as the planimeter readings, and by applying this formula we were able to express the area of the cross section in square microns, a more satisfactory unit. To avoid cumbersome figures, however, the area is expressed in square microns divided by 100. This change from planimeter units to the metric system will account for the differences between last year's data and those in the table shown herewith.

From the data in the table, as well as subsequent data to be presented, we are now able to discuss briefly the influences

of race, sex, age, and the region of the shaft sections on size and shape of the hair cross sections.

Race. The Maya have the roundest hair, with an index of 83 per cent, and the Negroes have the most elliptical hair, with an index of 57 per cent. The four Indian groups have hair which averaged together gives an index of around 80 per cent, as compared with 76 per cent for whites and 57 per cent for Negroes. Statistically these differences are significant and show a natural trend for hair shape. Intraracial differences, however, are often greater than interracial differences. For example, the area of the hair of 10 Negro individuals averaged 40.06 ± 0.35 square units, but in this group were individuals whose average hair area ranged from 28.45 to 50.96 units. For the Dutch, with the very low average area of 24.11, the range was between 14.5 and 33.6 square units. The variation in size and shape of individual hairs on one particular head is equally great. Nevertheless, the racial trends do exist.

Sex. Our data show definitely that males of all races have rounder hair than females for the ages from 9 to 19. These differences are significant for all races but the Dutch. In area the differences are not so pronounced, although in four of the races the male hairs are definitely larger than the female.

Female hair in our series seems more variable in its shape than male hair, as indicated by the coefficient of variation. This tendency is not true for hair size.

Age. The change in the size and shape of hair with age is a problem that is now being worked on. Although not all the data have as yet been actually calculated, the trend seems to substantiate that found by other workers, namely, that in young children the hair is small and round. The area rapidly increases after 5 years of age and remains fairly level until the fifties, at

which time there is a decrease. The index is high for the first 10 years of age but then drops off slightly. In all cases, however, the variation is very great. For this study only Maya hairs were used, a fact that insures homogeneity of the sample.

Size and shape of head hair along its shaft. In all the work on hair sections so far considered, the hair sample was taken within a few millimeters from the scalp in the occipital region. The section that was measured was made at about 20 mm. from the cut surface to insure uniform and comparable results. In the literature there are suggestions that the hair varies in size and shape along its shaft, but so far no conclusive evidence for this fact has been presented. To add further data on this topic, long hair samples were collected from 16 females: 7 American white, ages 50 to 70, and 9 Maya Indian, ages 10 to 20. In none of these samples has the hair been artificially curled or treated. From 80 to 100 hairs, all averaging 400 to 500 mm. in length, were sectioned at 20, 100, 200, 300, and 400 mm. from the original cut. The results show that the area at 100 mm. is greater than that at 20 mm. for 14 of the 16 samples. This is true irrespective of age or race. At the next 100 mm. the trend is not so obvious, for in only 9 samples does the area increase, and in 7 there is a decrease. In the successive intervals the trend is irregular. Some samples show a remarkable increase in size. In all but 2 cases the hairs at the terminal cut have a greater area than at the beginning.

If the samples are arranged in classes numbered I to VI as described in the table on page 254, we see at a glance the trends which occur in the shafts of samples from 16 individuals. For area, the tendency is to increase as the shaft grows out from the head, but for the index or the ratio of the maximum diameter to the

minimum, the tendency is to decrease as the hair is farther from the scalp. For example, for area there are no cases in class VI, steady decrease, and for index there are no cases in class I, steady increase. The meaning of all this is not yet clear. Undoubtedly long hair is elastic and hygroscopic, and its size and shape may well be influenced by environment. It is doubtful that dressing the hair alone causes the observed changes, for there is no consistent difference between the hair of whites and of Indians, and Maya

color was matched with the Fischer-Saller Haarfärbentafel. On this scale the graded samples run from A, a very light blond, to Y, a pure black. Red hair is considered separately on another scale ranging from I to VI.

If the colors are split into three groups—A to G, H to P, Q to Y—and the per cent frequency calculated for each year of age, one finds a steady decrease in the A-G group and a corresponding increase in the Q-Y. If the colors on the Fischer scale are given numbers from 1 to 24, corre-

DIRECTION OF CHANGE IN SIZE AND SHAPE IN HAIR CUT AT VARIOUS DISTANCES FROM THE SCALP

Class	Area	Index
I. Steady increase..	M17+ M19 M45 W73 W66*	.....
II. Increase then decrease..	M17 M13 M11 W68 W35	M17+ M19+
III. Increase then decrease then increase..	M17- W52 W53 W72	M14 W66
IV. Decrease then increase..	M14 M19+	M17 M45 W52
V. Decrease then increase then decrease..	.....	M13 M17- M19 W35 W53 W72
VI. Steady decrease	.....	M11 W68 W73

* M, Maya; W, white; 17, 19, 45, etc., age of individual.

women rarely do anything to their hair except wash it. From these preliminary observations we conclude that the hair flattens out and expands in size as it progresses from the scalp.

Change in hair color with age. It is generally known that hair color darkens with age. The degree or speed of darkening has never been measured quantitatively.

The material used in this study has the advantage over others in that it consists of a longitudinal series of growing children measured and recorded over a 10-year period. The sample consists of 220 male and 194 female children ranging in age from 6 to 18, all of American Dutch stock. Each time they were measured the hair

sponding to the letters, a correlation can be made between hair color and age. A coefficient of 0.526 ± 0.009 is obtained. The regression equation indicates that for each year in age the hair color will change almost 1 unit of the Fischer scale. Red hair also darkens, giving a correlation coefficient of 0.351 ± 0.054 . The coefficient is negative because on the Fischer scale the darkest red hair is I and the lightest is VI.

It is therefore evident that racial comparisons of hair color must be made with the clear conception that hair color is not a stable physical characteristic during the growth period. Due allowances should be made for hair material that has been analyzed from populations of unknown age.

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NUTRITION LABORATORY

Boston, Massachusetts

THORNE M. CARPENTER, *Acting Director*

The research program of the Nutrition Laboratory has proceeded more slowly this year because of the participation of several of the laboratory staff in work on national defense. Since the middle of January 1941 three of the staff have been engaged most of the time in this work. The training of the laboratory personnel and the equipment that has been accumulated since the beginning of the Laboratory have proved invaluable in this particular defense project. Because of the equipment on hand, it was possible to begin participation in the defense investigation in a short time, whereas if the equipment had had to be obtained commercially, there would have been a serious delay.

During the past year some definite objectives have been attained in our research program. The respiratory quotient of protein of the Dalmatian dog, a breed that excretes a larger amount of uric acid in the urine than do other breeds, has been shown to be lower than that accepted for many years as true of animals in general. The full significance of this finding is not yet evident, for it is not known at present whether the method of attacking the problem is such that other animals in addition to the Dalmatian dog may eventually be found to have a lower respiratory quotient of protein than has customarily been conceived.

The response of the rabbit to differ-

ent environmental temperatures prevailing prior to measurement of its metabolism at thermic neutrality has been established, and it has been shown that for comparative purposes these animals, much used in laboratory studies, should live for at least three weeks beforehand at the same environmental temperature at which their metabolism is to be measured.

The emission respiration calorimeter for human beings has been improved by the installation of a line of alternating current, which provides steadier voltage than the direct current in the neighborhood, and by the refinement of the apparatus for measurement of rectal temperature. With these two changes, it is expected that the heat production as calculated from measurements of the metabolism of nutrients in the body and the heat production as actually measured will agree better.

Construction of a modification of the thermic diaferometer of Noyons has been completed. This apparatus is an electrical arrangement designed to measure with a high degree of accuracy the content of carbon dioxide and the oxygen deficit of atmospheric air that has been changed by the breathing of man and other animals in a confined space. Tests have been made of the accuracy of the apparatus for analysis of the carbon dioxide content and the oxygen deficit of respiration-chamber air.

STAFF NOTES

On November 19, 1940, Dr. T. M. Carpenter represented the Carnegie Institution of Washington at the inaugural ex-

ercises of Northeastern University, when Dr. Carl S. Ell was inducted into office as President. In January 1941 he was ap-

pointed a National Councillor for the Northeastern Section of the American Chemical Society for the year 1941. On March 13, 1941, he was appointed a Consultant in Section L-12, in Division B, under the direction of the National Defense Research Committee.

On October 28, 1940, Dr. Howard F. Root, of the New England Deaconess Hospital, gave a paper (jointly with Dr. Carpenter) entitled "Studies of carbohydrate metabolism in cases of insulin resistance" at the annual meeting of the American Clinical and Climatological Association, at White Sulphur Springs, West Virginia.

On April 18, 1941, at the Chicago meeting of the American Physiological Society, Robert C. Lee gave a paper entitled "Effect of previous environmental temperature on the metabolism of the rabbit measured at 28° C."

At the eighth annual meeting of the American Institute of Nutrition, at Chicago, on April 16, 1941, Dr. Carpenter discussed the "Comparative respiratory metabolism of carbohydrates" at a symposium on the "Nutritive Significance of Indi-

vidual Carbohydrates." At the Chicago meeting of the American Society of Biological Chemists, on April 18, 1941, he gave a paper entitled "Respiratory quotient of the Dalmatian dog," jointly with Dr. H. C. Trimble, of the Harvard Medical School. His annual lecture on basal metabolism to the first-year class at the Harvard Medical School occurred on March 7, 1941.

Since the beginning of 1941 Robert C. Lee and George Lee have been engaged almost exclusively and V. Coropatchinsky has been engaged intermittently in national defense work.

Miss M. Joan Blakely has been appointed a full-time assistant for the studies on diabetes mellitus, under the grant allotted for this purpose.

During the year the Nutrition Laboratory has been visited by groups of students from the Harvard Dental School, from the class in advanced nutrition at the Massachusetts Institute of Technology, from Regis College in Weston, Massachusetts, and from the Home Economics Department of the Farmington Normal School in Maine.

INVESTIGATIONS IN PROGRESS

Habituation of the rabbit to various environmental temperatures and its effect on the basal metabolism. This study has been completed, and the results have been prepared for publication.

Relation of the rabbit's body composition to its basal metabolism. Analyses, begun last year, have been continued as opportunity has provided, and determinations of the fat and ash content of the rabbits have been completed. Further work is in progress. R. C. Lee has had charge of both of these rabbit studies and has been assisted by G. Lee.

Effect of body position on the respiratory quotient. In many of the measure-

ments of the respiratory quotient in this Laboratory, the position of the subject has been that of sitting in a chair. This is not the usual body position in studies of the resting metabolism, but as many of the determinations of the respiratory quotients of diabetic patients have been made with the patients in the sitting position, it has been important to establish whether the respiratory quotient of a subject while sitting is different from that while he is lying on his back. Experiments on normal college students have been carried out, in which the positions have been alternated on the same morning, the order of alternation varying from day to day. The

study has been completed, under the supervision of R. C. Lee, assisted by G. Lee.

Electrical method of gas analysis. The modified model of the thermic diaferometer of Professor A. K. Noyons has been tested further during the year, both for sensitivity and to establish the values for carbon dioxide content and oxygen deficit of gaseous mixtures per millimeter deflection of the galvanometer. As a further proof of the accuracy of the apparatus, samples of air from burning alcohol have been analyzed in consecutive series with respect to the ratio of carbon dioxide to oxygen in the combustion, i.e., the respiratory quotient. The analyses, made by V. Coropatchinsky, have progressed to such a point that a description of the apparatus, including the various control tests, has been prepared.

Effect of ingestion of hexoses on the respiratory quotient of the cat. This study, begun somewhat over a year ago, has now been completed so far as concerns the three sugars, galactose, fructose, and glucose. These sugars were given in varying amounts to several cats. The observations have been made by B. James.

Respiratory quotient of cats after ingestion of d-mannoheptulose. The sugar d-mannoheptulose is of interest because of its occurrence in appreciable amounts in the avocado pear and because, when this sugar is ingested by man, it is excreted in part in the urine. As a large number of experiments with other sugars and control experiments without sugar had been made on cats in this Laboratory, advantage was taken of the opportunity of using the results of these experiments for comparison with observations made on the effect on the respiratory quotient of giving 10 grams of d-mannoheptulose to cats. The investigation was carried out through the cooperation of Dr. Norman R. Blatherwick, of the Biochemical Laboratory of the

Metropolitan Life Insurance Company, New York City. The respiratory exchange measurements were made by B. James.

The emission calorimeter. Earlier studies have shown that the emission calorimeter for man in this Laboratory is extremely sensitive and highly accurate. The electric current used as a comparison source of heat elimination in this apparatus has presented some difficulties, however. Ordinarily the Laboratory is supplied with direct current, but because some rather large motors in the neighborhood are dependent on the same supply and these operate only intermittently, the direct current cannot be supplied with constant voltage. To obviate this difficulty, a special line has been installed from the Harvard Medical School Power House for supplying alternating current. With a special wattmeter, which measures either D.C. or A.C. watts, highly satisfactory control tests of the calorimeter have been made in which alternating and direct current have been compared, one of the currents being passed through the chamber intended for the human subject. Control tests with burning alcohol have also been made, the alternating current being used as the basis of comparison. These have proved far more satisfactory than such tests made heretofore with this calorimeter. The other factor having to do with the accuracy of the comparison of direct and indirect measurements of the heat production of man is the measurement of the body temperature. The rectal thermocouple has been refined so that the body temperature can be measured more accurately. V. Coropatchinsky has carried out the tests on this calorimeter, aided by R. C. Lee, G. Lee, and B. James.

Respiratory quotients of normal individuals during the day. In spite of the numerous determinations of respiratory quotients on patients and on normal indi-

viduals before and after meals, especially of pure substances, little is known regarding the normal course of the respiratory quotient during the day. A series of determinations of the respiratory quotient before and after breakfast and after the midday meal has therefore been made with a number of normal individuals at the Baker Clinic of the New England Deaconess Hospital, through the cooperation of Dr. H. F. Root. These observations, which were carried out by B. James, furnish the basis for comparison with the same type of determinations with diabetic patients.

Metabolism in diabetes mellitus. The respiratory exchange measurements on diabetic patients have been continued this

year, through a special grant from the Carnegie Institution and with the appointment as Research Associate of Dr. Elliott P. Joslin, Medical Director of the George F. Baker Clinic. The studies have been made with particular reference to the intravenous versus oral administration of glucose, the effect of ingestion of fructose, the condition of insulin resistance, with patients near coma and in acidosis, and throughout the day before and after breakfast and after lunch. The work has been pursued this year almost continuously on a full-time basis, with the cooperation of Dr. H. F. Root. The respiratory exchange measurements have been made by B. James, assisted by M. J. Blakely.

LITERARY WORK

An article on "Human carbohydrate combustion after oral versus intravenous administration of glucose" has been prepared by Dr. Carpenter, in cooperation with Dr. H. F. Root, of the New England Deaconess Hospital.

An article on "The respiratory quotient of protein of the Dalmatian dog" has been written by Dr. Carpenter and Dr. H. C. Trimble, of the Harvard Medical School.

A detailed report has been completed by

R. C. Lee on the "Heat production of the rabbit at 28° C. as affected by previous adaptation to temperatures between 10° and 31° C."

A detailed description of the modified Noyons thermic diaferometer has been prepared by Dr. Carpenter, with V. S. Coropatchinsky.

The preparation of publications and the editorial work have had the efficient supervision of the editor, Elsie A. Wilson.

PUBLICATIONS

- (1) *Skin temperatures of the pig, goat, and sheep under winter conditions.* Robert C. Lee, Nicholas F. Colovos, and Ernest G. Ritzman. *Jour. Nutrition*, vol. 21, pp. 321-326 (1941).

At air temperatures between -12° and +21° C., skin-temperature measurements were made on two sheep, a pig, and a goat. After change to a different air temperature, equilibrium in skin temperature was quickly established by the goat but more slowly by the pig. The sheep had a higher skin temperature than the goat and the pig under

all conditions, the goat's temperature being slightly lower and the pig's appreciably lower. The protective coats of the sheep and the goat made it possible for them to maintain their skin temperatures within fairly narrow ranges in spite of large differences in air temperature, but the poorer external protection of the pig did not permit such uniformity. Comparison of these skin-temperature measurements with previous measurements of the heat production of these same animal species at widely different environmental temperatures demonstrates that changes in skin tem-

perature cannot be used as an index of metabolic changes, but that differences in the external protective coat and the fat insulation in and beneath the skin may account for wide variations in skin temperature not correlated with heat production.

- (2) *Effect of previous environmental temperature on the metabolism of the rabbit measured at 28° C.* Robert C. Lee. Amer. Jour. Physiol., vol. 133, pp. P360-P361 (1941).

Abstract. (See page 260.)

- (3) *Report of the Chairman of the Northeastern Section of the American Chemical Society, Inc., to the members of the Board of Directors.* Thorne M. Carpenter. The Nucleus, vol. 18, pp. 11, 15, 21 (1940).

Report for the year 1939-1940.

- (4) *Comparative respiratory metabolism of carbohydrates.* Thorne M. Carpenter. Jour. Nutrition, vol. 21, suppl., p. 20 (1941).

Abstract of discussion. (See page 260.)

- (5) *Respiratory quotient of the Dalmatian dog.* Thorne M. Carpenter and Harry C. Trimble. Jour. Biol. Chem., vol. 140, Proc. p. xxiii (1941).

Abstract. (See page 260.)

- (6) *Energy metabolism.* Thorne M. Carpenter. Ann. Rev. Physiol., vol. 3, pp. 131-150 (1941).

A survey is made of the literature dealing with the energy metabolism of warm-blooded animals, published between October 1939 and September 1940. This survey includes the studies on basal metabolism and the studies on factors affecting metabolism; specifically, fasting, food supplies and food substances,

activity, body build, size, athletics, race, diseases, glands of internal secretion and hormones, drugs, season, climate, and environment. It is evident that there is a tendency toward increasing study of the effect on energy metabolism of environmental conditions, particularly with regard to external temperature.

- (7) *Studies of carbohydrate metabolism in cases of insulin resistance.* Howard F. Root and Thorne M. Carpenter. Trans. Amer. Clin. and Climatol. Assoc., vol. 56, pp. 1-10 (1941).

Untreated and uncontrolled diabetic patients have a low respiratory quotient (R.Q.) under postabsorptive conditions, but a few days' treatment with insulin results in a rapid rise in the quotient and a greatly increased response to glucose administered intravenously, indicating that insulin increases the proportion of carbohydrate oxidized in the metabolic mixture. Diabetic patients receiving insulin treatment show an increase in R.Q. under basal conditions, if the amount of carbohydrate in the diet is increased. When single doses of insulin and glucose are given at the same time intravenously, a marked rise in R.Q. can be produced, which is greater than will occur when glucose alone is given. Some diabetic patients show a resistance to insulin treatment and require several hundred units of insulin a day for a considerable period of time. If sufficient insulin is given, however, the R.Q. can be raised to a normal level, indicating at least a partial correction of disturbed carbohydrate metabolism. Possible explanations of insulin resistance are considered, especially the sparing effect of insulin on the islands of Langerhans.

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SPECIAL PROJECTS: BIOLOGICAL SCIENCES

PHILIP N. BRIDGES, Columbia University, New York, New York. *Revision of salivary-gland chromosome maps of Drosophila melanogaster.* (For previous report see Year Book No. 39.)

During the past year the revisions of the salivary-gland chromosome maps of *Drosophila melanogaster*, initiated by C. B. Bridges with his publication of the X-chromosome map in 1938 (*Journal of Heredity*, vol. 29), were completed. In last year's report (Year Book No. 39) completion of the maps of the right limb of the second chromosome and of the left limb of the third chromosome, and progress on that of the right limb of the third chromosome, were noted. Since that report the latter map has been completed, as has also the map of the left limb of the second chromosome.

For the entire series of revisions the same methods and materials were used. Aceto-carmine smears of the larval salivary glands were prepared, and the best of these were selected for well stretched and stained chromosomes. Camera lucida drawings at a uniform magnification of 5000 diameters were made, about ten for each of the twenty divisions of each of the chromosome arms, and these drawings were compared with one another for number, character, and intensity of the bands. A composite map was then made, the dimensions of each section being the averages of the separate camera lucida drawings, with the bands filled in from the series of drawings. The completed revisions are longer, because of the choice of more stretched chromosomes, and show more lines, with better relative intensities, spacing, and characteristics, than did the map of 1935 (C. B. Bridges, *Journal of Heredity*, vol. 26). All the revisions were published in a standard form, with the X-chromosome map mentioned above as a basis. That is, they were all reproduced at a magnification of 3100 diameters, all the lines were

numbered, with their characters indicated, and a correlation between the genetic and cytological maps was included. The last few revisions were drawn by a new technique which allowed them to be reproduced somewhat more intensely than were the earlier revisions.

All the revisions show a great increase both in length of chromosome and in number of bands over the original map of 1935. The X-chromosome revision contained 1011 bands, and was 414 microns long, as compared with the original 725 bands and chromosomal length of 220 microns. As stated in last year's report, the 2R-chromosome revision gave an increase from 660 to 1136 bands, and an increase in length from 245 to 446 microns. Likewise for the 3L-chromosome revision, the increase was from 542 to 884 bands, and from 210 to 424 microns. The present report adds the results obtained for the revisions of the 3R-chromosome and the 2L-chromosome maps. In the 3R-chromosome revision the increase is from 697 to 1178 bands, and from chromosomal length of 280 to 519 microns (fairly close to the estimated values of 1200 bands and 480 microns), and in the 2L-chromosome revision (to be published in the *Journal of Heredity*, 1942) the increase is from 584 to 850 bands, and from 205 to 385 microns.

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BARBARA S. BURKS, Genetics Record Office, Cold Spring Harbor, Long Island, New York, and Department of Psychology, Columbia University, New York, New York.
Research projects in the field of human heredity. (For previous reports see Year Books Nos. 36 to 39.)

The following report has been submitted with relation to studies undertaken with support of funds granted by the Carnegie Corporation of New York to the Carnegie Institution of Washington and to Columbia University, and by the Carnegie Institution to Columbia University.

During the first half of the year work was centered at the Genetics Record Office; during the second half at Columbia University. In preparation for this move, emphasis at the Genetics Record Office was placed upon completing studies in progress or bringing them to the point where they could be transferred without loss of momentum. Such studies included two on the transmission mechanism of single traits (short incisors and mid-digital hair), one on a search for linkage (in collaboration with Helen Wyandt, of the University of Nebraska, dominant oval red blood cells were tested for linkage against several normal traits), two on differential fecundity (to test R. A. Fisher's hypothesis that fecundity is minimal in groups rising rapidly on the social scale), and one on comparative development in a pair of monozygotic twins reared separately. These studies were mentioned and their results briefly discussed in last year's report (Year Book No. 39).

The study of the twins yielded evidence pointing to such clear relationships in mental, social, and emotional development both with heredity and with environmental variables that it may well be asked whether separated monozygotic twin pairs constitute better materials than any other for investigators in human genetics. Several additional pairs with whom correspondence has recently been opened

will be studied during the coming year.

A study of individuals separated from their own parents in early life and reared in foster homes has been continued, and has required an increasing expenditure of time. A subcommittee of the Social Science Research Council Committee on Social Adjustment (Subcommittee on Foster Child Studies) has been serving in an advisory capacity. Subjects have been selected from the case records of the State Charities Aid Association of New York so as to include three groups, in which (1) functional psychosis and (2) chronic alcoholism characterized at least one parent, and (3) normal adjustment to the demands of society characterized both parents. A follow-up schedule of tests and interviews is used for assessing the adult adjustments of the subjects. These adjustments will be viewed against the differences in parental background on the one hand, and against differences in foster-home background (e.g., socioeconomic status, training and discipline, marital compatibility of foster parents) on the other.

In connection with this project, a record-using study has also been undertaken to compare mental-test performance in infancy and early childhood of children whose first-year environments were in supervised boarding homes and in institutions. Preliminary results point to at least temporary retardation in development attributable to institutional environment.

As in previous years, a limited amount of time has been given to preparation of reviews of scientific studies in the fields of human genetics, human development, and population trends, and to editorial and consulting activities (on editorial boards of

professional periodicals, as consultant on study of the Negro in America, and as member of advisory board of Institute for Research in Child Psychology of Hunter College).

During the spring semester a biweekly seminar on the "nature-nurture" problem was organized at Columbia University, drawing its membership from faculty and graduate students in the departments of psychology, anthropology, and genetics, and from Teachers College, the School of Medicine, and several neighboring institutions.

Dr. Gladys C. Schwesinger, Miss Muriel Clark, and Miss Leah Levinger have assisted in the study of foster children, and Miss Marianne Bernstein in the studies of genetic transmission of traits. Mrs. Frances Carlson and Mrs. Bertha Edel have served as secretarial assistants.

W. E. CASTLE, University of California, Berkeley, California. *Experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3 to 38.)

Since the last report, Dr. Castle's investigations have been centered on two problems: (1) the influence of mutant color genes on body size in mammals, (2) the linkage relations of mutant genes in rats and rabbits.

The manner of the inheritance of body size has long been recognized as of importance both theoretical and practical, but until recently no method of investigating it directly had been devised. It appeared that numerous genes must be concerned in size inheritance, since F_1 individuals in general are of intermediate body size and variability is increased in F_2 . But no genes directly affecting body size had been identified until it was shown that certain color genes have such an influence. In mice it has been found that three mutant genes have a tendency to increase

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body size. These are the recessive mutations brown and blue, and the dominant mutation yellow, when heterozygous. When yellow is homozygous, as is well known, it is lethal.

It is noteworthy that brown, which occurs as a mutant in several other mammals, has been shown to increase body size also in rats and rabbits. Whether it has a similar action in dogs and horses and in birds has not been investigated.

Certain other mutant genes of mice, it has been found, have a tendency to decrease body size. Such are the mutations short-ear, dwarf, pink-eye, pink-eye₂, and leaden. Two other genes of mice, agouti and albino, have no apparent influence, either accelerating or retarding, on growth and so on adult body size.

The amount of change in adult body

size which any one mutant gene effects is in general not large, but in some cases cumulative or additive effects are observable. Thus brown (*b*) in mice increases body weight on the average by 4.3 per cent, dilute (*d*) by 2.1 per cent. Acting jointly they increase body weight by 5.8 per cent. Leaden (*l*) reduces body weight by 3.6 per cent, pink-eye₂ (*p*₂) by 5.5 per cent. Combined brown and leaden (*bl*) reduce body weight by 5.5 per cent, and combined brown and pink-eye₂ (*bp*₂) reduce body weight by 5.9 per cent.

Thus brown, which by itself or in combination with the favorable gene dilute increases body size, when in combination with the unfavorable genes leaden and pink-eye₂ has an opposite effect.

Investigations are in progress to ascertain the effect of yellow in various combinations and of another lethal gene, dominant white (*W*).

Linkage studies are designed to ascertain the location of mutant genes in particular chromosomes. This has been done with notable success in *Drosophila* (chromosome number 4), maize (chromosome number 10), and *Datura* (chromosome number 12). The problem is much more difficult in mammals, where the chromosome numbers are larger (20 in mice, 21 in the rat, and 22 in the rabbit) and known mutants are fewer. Nevertheless progress is being made toward the mapping of mutant genes in mammalian chromosomes. In the mouse eight chromosomes are known to contain two or more mutant genes each (Snell). Dr. Castle's own studies of linkage have in recent years been restricted to rats (in cooperation with Dr. Helen Dean King, of the Wistar Institute), and to rabbits (in cooperation with Dr. P. B. Sawin, of Brown University). The results to date may be summarized thus: In the rat three linkage systems have been demonstrated: Chromo-

some I contains five mutant genes, (1) Grüneberg's lethal (*l*), (2) albino (*c*), (3) red-eyed yellow (*r*), (4) pink-eyed yellow (*p*), and (5) waltzer (*w*). The linkage map is

	<i>l</i>	<i>c</i>	<i>r</i>	<i>p</i>	<i>w</i>
0	3.3	3.8	23.3	58.6	

Chromosome II contains the three mutant genes (1) Curly (*Cu*), (2) anemia (*an*), and (3) brown (*b*). The linkage map is

	<i>Cu</i>	<i>an</i>	<i>b</i>
0	1.8	45	

Chromosome III contains the two mutant genes (1) hairless (*hr*) and (2) wobbly (*wo*), between which the map distance (crossover percentage) is 39.6.

In the rabbit five linkage systems have been demonstrated; that is, five chromosomes are known to contain each two or more mutant genes. They are, in the order of their discovery, as follows: Chromosome I contains the three genes (1) albino (*c*), (2) yellow fat (*y*), and (3) brown (*b*). The linkage map is

	<i>c</i>	<i>y</i>	<i>b</i>
0	14.4	42.8	

Chromosome II contains the three genes (1) Dutch spotting (*du*), (2) English spotting (*En*), and (3) long or angora hair (*l*). The linkage map is

	<i>du</i>	<i>En</i>	<i>l</i>
0	1.2	14.9	.

Chromosome III contains two genes for short (rex) hair (*r*₁ and *r*₂), between which the crossover percentage is 17.2. Chromosome IV contains three mutant genes, (1) agouti (*A*), (2) dwarf (*dw*), and (3) wide band (*w*). The linkage map according to the best present information is

	<i>A</i>	<i>dw</i>	<i>w</i>
0	12.1	30.1	

Chromosome V contains two mutant genes, furless (*f*) and brachydactyl (*br*), between which the crossover percentage is 26.1.

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PAUL S. CONGER, United States National Museum, Washington, District of Columbia.
Investigations and preparation for publication of results of studies on Diatomaceae.
 (For previous reports see Year Books Nos. 18 to 39.)

A period of six weeks in the summer of 1940 was occupied in field work and investigation at the Chesapeake Biological Laboratory, during which time it was possible to secure for study good quantities of very pure diatom material of several types. During this time also a special course on diatoms, covering all phases of the biology, paleontology, and economic importance of these organisms, was offered as a graduate course with an enrollment of six students. Increasing applications of the science of diatoms to certain fundamental problems of biology, oceanography, and industry appear to create a growing demand for, and a justification of, this course, now in its sixth year.

Following this, a month of field work under the auspices of the University of Wisconsin at their Limnological Laboratory at Trout Lake, in the northern lake district of the state, was devoted mainly to obtaining complete cores of the post-glacial sediments of various representative lakes, by means of the Jenkins sampler, built by the University. With this instrument, which works on the principle of a smooth penetrating surface about which a core segment is subsequently cut by a rotating lateral cutting face, it seemed pos-

sible to secure uncontaminated sediments through the entire thickness of lake bottom down to the original glacially formed basin. Thus cores were obtained to a depth of 30 feet, representing perhaps as much as 20,000 to 30,000 years of post-glacial deposition. Material was later obtained from one core penetrating 42 feet of sediment, by means of the Wilson sampler, a device of, if anything, even more positive accuracy. These materials, as yet but partially studied, show an interesting stratification, indicating changes in ecological and climatic conditions through the period covered, and also throw light on the rate and conditions of deposition of important materials.

Further data were obtained, both from collections made and from the records of Drs. Birge and Juday, concerning the close correlation between diatom productivity, pH, and dissolved silica content of the water, in several hundred widely variable lake waters.

The writer's presence in Wisconsin at this time made it convenient to take advantage of the opportunity to attend the Symposium on Hydrobiology held at the University of Wisconsin from September 4 to 7, and to present two papers, one on

"Silica relationships of diatoms," and the other on "Hydrobiological significance of diatoms." In the former the various aspects of silica supply, utilization by diatoms, and deposition were covered. In the latter three main points were stressed: (1) the relation of diatoms to sanitation and water supply, (2) the importance of diatoms as a chief synthetic factor in the aquatic food cycle, and (3) the function of diatoms in the formation of important siliceous deposits and oil residues. Abstracts of these papers were prepared for inclusion in the Proceedings of the Symposium, now in press. Nothing can better attest to the importance of these quiet but steady processes of Nature than the vast amounts of diatomaceous and oil-bearing sediments in the bottoms of innumerable Wisconsin lakes, and others. Examination of these materials was continued during the winter.

Examination was also made of core samples rich in diatomaceous material from the Klamath Lake region of Oregon, collected by Dr. L. S. Cressman in connection with his study of the objects associated with early man in this region. Similar materials from Wyoming were examined for Dr. Edgar Howard, but were found to contain no diatoms. An ever growing number of requests for information and for samples of special diatom materials were answered during the year.

A large quantity of concentrated diatom material, composed practically entirely of one species of delicate linear diatom, was supplied to the Johns-Manville Corporation for special studies of the physical properties, adsorption, and filtering qualities of this type of diatom in mass. This material is quite different in its composite texture from most diatomaceous earths, and affords an excellent opportunity for comparative tests.

A résumé of the literature on silicosis

as related to the diatomaceous-earth industry, and the effects noted and precautions taken in the processing of diatomaceous earth, was prepared for a professor investigating this subject at the University of Pennsylvania Medical School.

Cooperation with the Botany Department of the University of Toronto in selecting and supplying a number of species of diatoms particularly favorable for experimental photography with the electron microscope, and for comparing the latter's powers of resolution with those of the ordinary optical microscope, made it possible to obtain some photographs of diatoms by the electron microscope, ranging in magnification from 13,000 to 20,000 diameters. These pictures are of unusual interest in finally revealing the ultimate structure of some of the most minute and intricately sculptured diatom shells, a subject which had previously proved beyond the powers of ordinary microscopy, and until the advent of the electron microscope seemed one of the unsolvable questions of diatom morphology. This method thus opens up the eventual possibility of obtaining a complete knowledge of the morphology of diatom shells, a matter not only of considerable importance to an understanding of the physiology and growth of diatoms, but with a direct bearing on their physical properties from the standpoint of industrial application. Through the courtesy of Drs. Hamly and Watson, of the University of Toronto, permission was received to publish one of these pictures in the paper listed below, and this constitutes one of the earliest illustrations of a diatom by means of the electron microscope. It is to be hoped that more work of this nature on diatoms may soon be done.

The literature on the present status of the question of the relation of diatoms to petroleum origin was summed up for a chemist at Columbia University.

A résumé of the status of work done on diatom cultivation for oyster feeding was prepared for the Connecticut Oyster Farms Company, where a very pioneering and progressive approach is being made toward this subject, of seemingly great potential value.

Identifications of plankton diatoms were made for the Stream Pollution Laboratory of the U. S. Public Health Service at Cincinnati, Ohio.

TH. DOBZHANSKY, Columbia University, New York, New York. *Studies on the genetic structure of natural populations.* (For previous reports see Year Books Nos. 37 to 39.)

The amount of concealed genetic variability carried in the germ plasm of sexually reproducing organisms may be supposed, on theoretical grounds, far to exceed the amount of variability actually observable in structural and physiological characteristics. This concealed variability comprises recessive mutant genes and chromosomal variants which are detectable only with the aid of special methods. For technical reasons, studies on concealed variability have been carried out chiefly on flies belonging to the genus *Drosophila*. The store of recessive mutants present in natural populations of these flies proved to be large indeed. As reported previously (Year Books Nos. 37-39), from 15 to 30 per cent of the third chromosomes of *Drosophila pseudoobscura* inhabiting certain localities in California, Mexico, and Guatemala contain recessive lethals or semi-lethals. Aside from these, some of the third chromosomes carry genes modifying the viability, development rate, fertility, and other characters. The behavior in this respect of chromosomes other than the third long remained unknown, since no satisfactory machinery for their genetic analysis was available. Two years ago, however, Mr. E. Novitski, by means of an X-ray treatment, induced an inverted sec-

Extensive accessions of material and records were added during the year to the collection of diatoms which is domiciled at the U. S. National Museum, and which is so basic to the pursuit of studies in this subject.

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tion in the second chromosome of *D. pseudoobscura*, and in 1940 Mr. G. T. Rudkin accomplished a similar task for the fourth chromosome. This leaves at present only the small fifth chromosome not under experimental control. The X chromosome cannot harbor many concealed mutant genes.

An analysis of the concealed genic variability in the second and fourth chromosomes has been undertaken in collaboration with Miss A. M. Holz and Mr. B. Spassky. Samples of populations of *D. pseudoobscura* collected mainly on Mount San Jacinto, California, served as material. A special effort has been made to detect the minor modifiers of the viability and of other characters which are present in these chromosomes. The genetic technique applied to accomplish this end will be described elsewhere; in principle it is identical with that used for the detection of lethals. That is, a series of crosses is made designed to obtain flies homozygous for a given wild chromosome. The test experiment with a given chromosome can be repeated as many times as necessary to insure that the results obtained have a given degree of statistical significance.

Among 248 second chromosomes so far analyzed, roughly 22 per cent carried reces-

sive lethals or semilethals. Almost exactly the same figure was obtained for the 224 fourth chromosomes analyzed. The corresponding figure for the third chromosomes (obtained in 1939 in a much larger sample) is 13.85 ± 0.65 per cent. Since every fly carries each of these chromosomes in duplicate, it is easy to compute that only about 60 per cent of the individuals of *D. pseudoobscura* inhabiting Mount San Jacinto are free of lethals and semilethals in their second chromosomes, 35 per cent carry a lethal or a semilethal in one, and about 5 per cent carry a lethal or a semilethal in both of their second chromosomes. The situation concerning the fourth chromosomes must be similar. As to the third chromosomes, about 74 per cent of the individuals must be free of lethals, 24 per cent must carry a lethal or a semilethal in one, and 2 per cent in both chromosomes. Taking into account all the chromosomes, only about 27 per cent of the flies are probably free of lethals, 39 per cent carry one, 31 per cent carry two, and 3 per cent carry three or more lethals or semilethals.

A recessive semilethal is arbitrarily defined as a gene which, under the conditions of the experiment, destroys 50 or more per cent of the individuals homozygous for it. Evidently, there is no sharp dividing line between semilethals and genetic modifiers causing relatively minor deteriorations of the viability of their carriers. The frequency of such modifiers can be determined only roughly, since, no matter how extensive and painstaking the experiments may be, the effects of some modifiers are so small that they are undetectable. Among the 248 second chromosomes so far analyzed, approximately 25 per cent contained genetic factors which lower the viability to a perceptible extent (this is a preliminary estimate which will probably be changed when the analysis of the data is complete). The correspond-

ing figure for the 224 fourth chromosomes analyzed turns out to be 49 per cent. The discrepancy of the figures for the second and the fourth chromosomes is likely to be spurious: these figures are based on data which require certain correction factors to be taken into account; corrected figures will be published later. It appears, however, that in the San Jacinto populations of *D. pseudoobscura* at least 50 per cent of the second, third, and fourth chromosomes carry lethals, semilethals, or deleterious viability modifiers. If this estimate is accepted, it follows that less than 2 per cent of the flies in these populations do not carry at least one deleterious recessive gene of some kind in heterozygous condition.

Between 1 and 2 per cent of the second and fourth chromosomes tested seem to contain modifiers improving the viability of the homozygotes above the level of an average heterozygote (the latter is being taken as the "standard" or "normal" viability). The existence of such modifiers raises a theoretically difficult problem. Though some biologists have doubted that evolution can be based on accumulation of gene mutations, owing to the latter's being almost always deleterious, from the modern point of view it is rather the supposition that favorable mutants may frequently occur in nature that seems paradoxical. For if such mutants do occur, what prevents their speedily supplanting the present "normal" type? Among the possibilities to be tested in future experiments, the following appear most probable: (1) the observed "favorable" mutants "improve" the viability of the fly only under experimental but not under natural conditions; (2) since the natural environment is constant neither in space nor in time, the species has a multitude of "normal types" with different requirements for optimum development.

The analysis of the data on the fre-

quency of second and fourth chromosomes containing modifiers of the development rate is not complete. Preliminary estimates show that approximately 50 per cent of the chromosomes slow down and between 0.5 and 12 per cent of the chromosomes accelerate the development of the homozygotes. It must be noted that the homozygotes which have subnormal viability display a retardation of development more frequently than do those with normal viability (thus suggesting that some genetic factors affect the viability as well as the development rate). This correlation is, however, far from absolute: some semilethals have no effect on the development rate, and some factors which retard development very appreciably cause no deterioration of viability.

To test the fertility of the flies homozygous for wild second or fourth chromosomes, females and males from a given strain were placed in culture bottles and allowed to produce offspring. If no offspring appeared, the tests were repeated; a second failure was taken as evidence of the presence of sterility factors in the respective chromosomes. Among the 207 second chromosomes tested, 10.6 per cent gave sterile homozygotes; among the 170 fourth chromosomes, 8.8 per cent displayed a similar behavior. The sterility tends to be correlated with low viability and with retardation of development, but this correlation is far from complete.

Observations on the variability of the gene arrangement in the third chromosome of *D. pseudoobscura* have been continued. As reported last year (see Year Book No. 39), populations inhabiting not only regions hundreds of miles apart but even localities ten miles from each other may be distinct in the relative frequencies of the gene arrangements present in them. Furthermore, the composition of the population within a given locality does not

remain constant in time, but may undergo changes from month to month. To account for these temporal changes, a provisional hypothesis was advanced, according to which the population found at a given collecting station at a given time represents mainly the offspring of a relatively few individuals which had by chance discovered and monopolized an abundant food supply. This hypothesis is no longer tenable, because it is now known that (1) the changes in the relative frequencies of the gene arrangements within the population of a given station tend to follow a seasonal cycle, and (2) the habits of *D. pseudoobscura* are less sedentary than was formerly supposed.

A summary of the data on the frequencies of the different gene arrangements in populations of three localities on Mount San Jacinto is presented in the table on page 274. The data are grouped according to the month of collecting, the samples obtained in 1939 and in 1940 having been combined. The frequencies of the gene arrangements are expressed in percentages. At Andreas Canyon and at Piñon Flats the frequency of the Standard arrangement is highest during the cool period of the year, and reaches a minimum during the summer months. The behavior of the Chiricahua arrangement is the opposite of that of the Standard. Arrowhead exhibits no definite seasonal trend at Andreas, but seems to be commoner during the summer than during the spring and fall at Piñon. At Keen, no significant changes took place during 1939, but in 1940 the Standard arrangement seemed to increase in frequency as the summer progressed. Preliminary data for 1941 tend to confirm the existence of the seasonal trends in the frequencies of the gene arrangements in the Mount San Jacinto populations. The best working hypothesis to account for such seasonal changes would

seem to be that some of the gene arrangements in the third chromosome of *D. pseudobscura* differ in adaptive value from

sponse of the species is so rapid that the seasonal climatic cycle is reflected in the genetic composition of the population.

MONTH (1939 and 1940)	GENE ARRANGEMENT (PER CENT)				NUMBER OF CHROMOSOMES EXAMINED
	Standard	Arrowhead	Chiricahua	Others	
ANDREAS CANYON					
January.....	56.0	30.0	12.0	2.0	200
February.....	58.3	27.8	11.3	2.6	230
March.....	62.4	21.2	12.7	3.7	518
April.....	55.0	19.8	21.2	3.9	358
May.....	48.7	28.6	19.6	3.1	224
June.....	40.9	24.6	30.9	3.6	110
July.....	....	....	....	...	...
August.....	....	....	....	...	...
September.....	55.1	24.3	17.4	3.2	218
October.....	56.2	30.5	11.0	2.4	210
December.....	53.3	28.6	15.9	2.2	182
Totals.....	55.8	25.1	16.0	3.1	2250
PIÑON FLATS					
March.....	44.6	20.2	30.0	5.2	386
April.....	38.8	28.7	28.3	4.2	237
May.....	28.1	31.9	34.4	5.7	442
June.....	26.9	32.4	36.4	4.3	324
July.....	....	....	....	...	...
August.....	35.9	33.3	25.6	5.1	156
September.....	45.2	23.5	28.2	3.1	294
October.....	54.6	25.4	16.6	3.5	284
Totals.....	38.6	27.6	29.4	4.5	2123
KEEN CAMP					
April.....	30.8	23.4	41.9	4.0	504
May.....	28.9	24.4	43.2	3.5	824
June.....	28.4	25.7	42.3	3.6	1446
July.....	31.2	27.3	37.3	4.1	1018
August.....	33.5	27.6	35.4	3.4	322
September.....	30.3	30.3	35.6	3.9	208
October.....	26.1	43.5	26.1	4.3	46
Totals.....	29.9	26.1	40.3	3.8	4368

other gene arrangements; that the species population in at least some localities is a mixture of types with different ecological requirements; and that the adaptive re-

The ecological potentialities of a chromosome with a given gene arrangement need not necessarily depend on that arrangement as such; it is more likely that the

chromosomes with different gene arrangements found within a population differ in gene contents. This latter supposition seems to be borne out by the fact that the cycles for the same gene arrangement do not necessarily coincide even in localities geographically so close as Andreas, Piñon, and Keen (these localities are 10 to 15 miles apart, yet the Standard arrangement at Andreas and Piñon becomes rare in summer, whereas at Keen it either does not change in frequency or becomes commoner during the warmest months). Further observations and experiments bearing on the above problems are being planned.

Professor Sewall Wright, of the University of Chicago, has undertaken a mathematical analysis of the data on concealed genetic variability in *D. pseudoobscura*, in an attempt to determine the order of magnitude of certain constants of population dynamics, such as the population number N, the inbreeding and migration coefficients, and others (see paper by Dobzhansky and Wright listed in bibliography below; further reports are to follow). In connection with this work it has become necessary to clarify certain aspects of the biology of the fly, and first of all to secure information regarding its mobility and its population density in natural habitats. Experiments to this end were carried on during the summer of 1941 on Mount San Jacinto, California, in collaboration with Messrs. Harlan Lewis, A. Sokoloff, and B. Wallace. A modification of the technique developed by Professor N. W. Timofeeff-Ressovsky, who has recently described similar experiments conducted on *D. funebris* and *D. melanogaster* in Europe, was used. The first experimental fields consisted of 45 trap bottles arranged in a checkerboard pattern 10 meters apart. A known number of individuals of *D. pseudoobscura*, marked

either by a visible mutant (orange eyes) or by a drop of "platinum" nail polish applied to the thorax of the fly, were released at the center of the field. The 45 traps were exposed daily after the release of the marked flies, and the marked as well as the unmarked flies found in them were counted, recorded, and liberated at the point of capture. It became evident at once that this technique is unsuitable for *D. pseudoobscura*, since some of the marked flies reached the margins of the field and some passed beyond the margins within 24 hours after release. The experimental fields were then enlarged so that the spaces between the traps equaled 20 meters, but even this arrangement was found unsatisfactory. Next, the traps were arranged in two lines intersecting to form a cross, and marked flies were released at the intersection. Such cross-shaped fields were made having the branches of the cross 110, 220, and 440 meters long.

To find out whether the migration rates of the flies marked by mutant genes or by the nail polish are comparable with those of wild flies, the following control experiment was arranged. Wild flies were collected daily on a field with 45 traps arranged in checkerboard fashion 20 meters apart; the flies were counted and then destroyed. After several days of such a "depletion experiment" most of the flies still present on the field are, evidently, either recent immigrants or newly hatched individuals. Their number and distribution within the field are a function of the mobility of the wild flies. Since no analysis of the data has yet been made, no definite conclusions can be reported here. One fact is, however, clear enough: the mobility of *D. pseudoobscura* is far greater than Timofeeff-Ressovsky's data suggest to be the case with *D. funebris* and *D. melanogaster*.

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CHARLES ELTON, Bureau of Animal Population, Oxford University, Oxford, England.
Research on natural fluctuations in North American animal populations. (For previous reports see Year Books Nos. 37 to 39.)

The grant of the Carnegie Corporation of New York, through the Carnegie Institution of Washington, has permitted the continuation of a large part of the study of North American animals despite war conditions. Charles Elton's book ("Voles, mice and lemmings: problems of population dynamics") is now in page proof. He and Mrs. Mary Nicholson have completed a paper on the muskrat cycle, and a further joint paper on fluctuations in the lynx is already far advanced. This latter study has necessitated an extensive historical analysis not only of fur returns, but of the fur districts of the Hudson's Bay Company since 1821. As there have been considerable changes in the administrative system, the fur returns of a district covered different areas at different times. These changes are now recorded in a series of maps and diagrams prepared by Mrs. Nicholson. She has also progressed with a subject index of all information available in the Bureau of Animal Population on fluctuations in some 30 species of wild animals from 1800 to the present day.

The "Canadian Arctic Wild Life Enquiry, 1939-40" (by Dennis Chitty and Helen Chitty) is now in press. This is the fifth year's analysis of reports from men in the Arctic about changes in lem-

tings, arctic foxes, and snowy owls, which in the East, at any rate, have a 3- to 4-year cycle of abundance. A preliminary review of the evidence seemed to show that there were regional differences in the phase of the lemming cycle during the period studied; for example, that a peak in numbers was passed one or two years earlier to the north and west of Hudson Bay than on Baffin Island. The limitations of the data are the small number and subjective nature of the observations, but as a system of recording the main outlines of current events the inquiry has fully justified itself. It is hoped that the results of this inquiry may some day be used as a guide in planning the distribution of field stations in the Arctic. The cooperation of the Northwest Territories Administration, Ottawa, and of the Hudson's Bay Company is hereby acknowledged.

The eighth annual report on changes in snowshoe rabbit abundance was published in 1940 and covered the period 1938-1939. The 1939-1940 results have been mapped except for certain reports which had to be duplicated and so arrived late. Recovery continued in both years after a widespread decline that started about 1933-1934 and eventually affected populations throughout Canada, Alaska, and the east-

ern United States. The reports were collected by the National Parks Bureau, Ottawa, the Hudson's Bay Company, the Biological Board of Canada, and the United States Bureau of Biological Survey.

This study, like the Arctic inquiry, has established the fact that there are pronounced regional differences in phase of abundance. Almost enough material is now available for a detailed analysis of the areas affected by the 9- to 10-year cycle and of the sequence in which the peaks of abundance were reached in different parts of the animal's range. It is hoped that a start will soon be made on this; but as a great deal of work is required to pro-

duce the two annual papers, a more comprehensive description may be some time in preparation. The mapping and analysis of the reports from both inquiries for 1939-1940 have been done by Mrs. Helen Chitty.

Further records were received of the number of embryos in snowshoe rabbits at South Indian Lake, Manitoba, throughout the breeding season of 1940.

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ARTHUR T. HERTIG and JOHN ROCK, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryology, embryological pathology, and reproductive physiology*. (For previous reports see Year Books Nos. 36 to 39.)

These studies have been continued with financial support of the Carnegie Institution of Washington, but additional financial assistance has been obtained by Dr. Rock for these joint studies from the William F. Milton Fund of Harvard University and the Committee on Problems of Sex of the National Research Council.¹

Since the last report, two additional human pre-villous ova have been recovered prior to the first missed menstrual period. It is impossible to give their exact anatomical

ages, since both are pathological. Since this phase of the problem was undertaken in 1938, eight early human ova have been recovered, including the two mentioned above. These have all been serially sectioned and form a part of the Carnegie Embryological Collection. Four of these eight specimens are pathological. Inasmuch as all these ova are still implanted in the uterus, it will thus be possible to study the pathogenesis of spontaneous abortion from a new aspect. Heretofore, studies on the pathogenesis of this common condition have utilized abortuses after their expulsion from the uterus. This series of ova *in situ*, small as it is, is the first that has been available for study of the entire ovum and implantation site of an inevitable abortion during the stages when the abortion is being caused but before there is any clinical evidence thereof.

The youngest of these pathological ova (the youngest one ever obtained) is little more than a tiny empty trophoblastic shell

¹ Since 1938, the two authors have collaborated in the search for early human fertilized ova. Because of the additional technical and secretarial assistance needed for such collaboration, part of the Carnegie grant-in-aid since 1939 has been spent in defraying a part of Dr. Rock's technical expense. Similarly, a part of Dr. Rock's grants has been used in defraying technical and secretarial expenses involved in Dr. Hertig's researches. This collaboration has, from a practical aspect, resulted in the merging of two separate but closely related research programs into a common program, still supported by the three grants-in-aid.

in which there is no embryonic rudiment. For years it has been discussed whether this sort of ovum (constituting one of the common types of spontaneously aborted ova) really was defective to begin with or whether it became pathological because of its environment. Since this specimen was obtained soon after implantation, its study will probably shed some light on this problem.

The three other pathological specimens show varying degrees of malformation of the trophoblast. Again, the more mature counterparts of such ova are encountered among abortuses spontaneously expelled from the uterus. One of the specimens shows almost a complete aplasia of the future chorion, a defect which would undoubtedly have a deleterious effect upon the embryo although the latter has not yet been affected.

These trophoblastic defects may also serve to slow up normal metabolic and developmental processes within the embryo so that they may be more correctly interpreted. Thus one of the pathological specimens (mentioned in Year Book No. 39) showing a defective chorion reveals a transitional stage between the large exocoelome and the true yolk sac. The formation of the latter is little understood in the human and only imperfectly so in the only other primate adequately studied—the macaque. It would appear that this specimen is analogous to a slow motion picture of a rapid process, the trophoblastic defect possibly helping to slow down an embryonic process, namely the formation of the yolk sac, so that it can be visualized and understood. The large exocoelome, bounded by Heuser's membrane and the endoderm, is in the process of breaking up into a series of smaller cavities, one of which may become the definitive yolk sac; or it may be that the latter forms in some other fashion among the

debris of the broken-down exocoelomic membrane. Be that as it may, this specimen, defective as it is, sheds some light on an important phase of embryonic development that has escaped study in all the other young human ova thus far obtained.

The comparable series of four normal human ova, obtained before the first missed menstrual period and fixed, stained, and serially sectioned by the same techniques, acts as a control for the study of the pathological specimens. Two of the normal ones (the 11- and 12-day specimens) have been completely studied and written up, and the report is to be published this year in volume 29 of the "Contributions to Embryology." Of the other two, estimated to be 14 and 16 days of age, only the former has been described in previous reports (Year Book No. 39). Since then the 16-day specimen has been sectioned and is found to be a beautiful example of an early villous ovum with an early yolk sac. Heretofore, this stage had been only imperfectly represented in the Carnegie Embryological Collection. The "border zone" of the implantation site of the 14- and 16-day specimens, a subject of study by Dr. Elizabeth Ramsey, of the Department of Embryology of the Carnegie Institution of Washington, is first forming in these two specimens, and therefore they serve as excellent material for the study of this zone of reaction between the ovum and maternal tissues.

The series of hydatidiform moles has now reached nearly 200 specimens, and a final correlation between the various morphologic aspects and the clinical outcome of the patients is in process of preparation for publication this coming year.

Following is a summary of the researches in which Dr. Rock is primarily interested:

During the year beginning July 1, 1940, 122 follicular ova have been added to the

previous collection of 412. Most of these are accompanied by menstrual information and specimen of endometrium and follicle. This will permit correlation between the condition of the ovum and its temporal position in the menstrual cycle.

A series of 125 ova has been serially sectioned and stained for study, and 45 more are now being prepared for sectioning. A number of these eggs had been cultured in serum for varying lengths of time. Of this group some had then been exposed to semen-free suspensions of spermatozoa.

The work on spermatozoa has been concerned chiefly with attempts to obtain a semen- and bacteria-free suspension in a medium suitable for insemination in vitro. At present blood serum seems the most favorable medium into which spermatozoa will spontaneously migrate from semen.

A series of nearly 90 young corpora lutea is being examined with a view to correlating their histology with that of the respective endometria, time in cycle, cytology of ova present in the ovary, etc.

In many instances where early corpora lutea were found, the corresponding tube was washed in an attempt to recover the recently ovulated egg. In one patient, operated upon on the 14th day of the cycle, a tubal ovum was obtained which was identified as such in the fresh state. After photography and fixation, this was sent to the Department of Embryology of the Carnegie Institution of Washington, where it is now being serially sectioned.

Since in the literature there are to our knowledge not more than seven instances of human tubal ova identified with certainty, this finding is of interest, particularly in view of the comprehensive collateral data which accompany it. These include: (1) an accurate record of lengths of cycles for six months prior to operation, as well as dates of onset of menstrual attacks of pain (*Mittelschmerz*) during the same period; the number of hours between the onset of the characteristic pain and the laparotomy which resulted in the finding of the tubal egg was noted; (2) sections of endometrium, corpus luteum (routine and special stains), and tube; (3) a 48-hour preoperative urine specimen, which is being analyzed for steroid hormone content. As soon as the microscopic sections and chemical analyses are completed, this case will be reported in detail.

Pending the finding of a human tubal fertilized egg, for which we are continuing to search, or the successful fertilization in vitro of either a tubal or a mature ovarian ovum from a patient at ovulation time, we have been perfecting the technique for in vitro culture of tubal fertilized rabbit eggs in a continuous-circulation apparatus. The changes in development from the one- or two-cell stage are being recorded by means of motion pictures. We are now prepared to repeat this procedure with a human fertilized egg whenever one is obtained.

ELLIOTT P. JOSLIN, New England Deaconess Hospital, Boston, Massachusetts. *Studies of carbohydrate metabolism in diabetes at the New England Deaconess Hospital*

The necessary equipment for determining the respiratory exchange and the respiratory quotient was established at the Deaconess Hospital in one of the laboratories in the George F. Baker Clinic in 1939. Although during the first part of

the period experiments were conducted only on occasional patients presenting special problems, during the past year and particularly since the fall of 1940 more frequent observations have been made.

With more than one hundred diabetic

patients as well as with a small group of normal controls, a series of observations has been conducted bearing upon the nutritional disturbance in diabetes. For more than one hundred years a fundamental problem in this disease has been the question whether the chief fault is inability to utilize carbohydrate on the part of the muscles, skin, and other tissues of the body, or whether the difficulty arises from the overproduction of glucose from fat, protein, and glycogen. The proponents of the latter concept have regarded the liver as being a central point in the disturbance. It has been possible to study the most severe types of metabolic disturbances, such as cases of diabetic acidosis and diabetes associated with liver disease, as well as patients in mild and moderate stages of the disease. The results so far tend to show that insulin has a fairly constant effect in

raising the respiratory quotient and improving the utilization of carbohydrate, provided the necessary quantitative relationships are observed. Thus, in the case of patients with highly resistant diabetes studied at the Deaconess Hospital, in some instances as much as 2000 units of insulin a day were taken, whereas an ordinary dose is 40 or 50 units. In such problems it has been necessary to make repeated determinations, sometimes as many as eight or ten, over a prolonged period of time. The results of experiments carried on to study the problem of insulin resistance have been published in the *Transactions of the American Clinical and Climatological Association* (see report of Nutrition Laboratory, pp. 260, 263), and another report on the utilization of glucose when given by vein in contrast with its administration by mouth is in press.

CHARLES W. METZ, University of Pennsylvania, Philadelphia, Pennsylvania. *Chromosome studies on Sciara*

Since the present report covers only a few months' work, it necessarily deals with investigations in progress rather than with completed studies. For this reason it will be confined to a description of the work, without detailed data. In the main the work represents a continuation of investigations under way in 1940. These fall into three groups, as follows:

1. A study of the structure of the giant salivary-gland chromosomes of Diptera. This is designed to throw additional light on the physical nature of genes. A review of the work done in the Department of Embryology of the Carnegie Institution in this field was presented at the Cold Spring Harbor Symposium on Quantitative Biology in June 1941. The studies continue to support the previous view that no microscopically visible parts of the chromatic

disks in these chromosomes represent individual genes.

2. A study of the problem of chromosome evolution, using the giant salivary-gland chromosomes of the fungus flies, *Sciara*. The recent work extends to additional species the previous finding that in *Sciara ocellaris* Comst. the common type of spontaneous chromosome alteration recoverable in nature is what has been referred to as minute deficiencies and duplications of parts. The possible evolutionary significance of these changes has been treated in earlier reports of the Department of Embryology. In addition, these studies have brought out the unexpected fact that different species of *Sciara* seem to differ considerably as regards spontaneous aberrations. Following some preliminary observations by Metz and Boche, it has been

found by Mr. Hampton Carson and Mr. Miles McCarthy that in *S. impatiens* and some other species of *Sciara* large chromosome rearrangements of the type commonly found in *Drosophila* (mainly inversions) are found frequently in nature. It is hoped that a full report may be given later on this work.

3. A study of the problem of induced chromosome changes. This bears not only on the question of chromosome evolution, supplementing that just described, but also on the question of chromosome structure and the nature of genes. As described in an earlier report, Metz and Boche found that in the eggs of newly hatched females of *Sciara* the chromosomes are apparently in a condition which makes them resistant to irradiation by X rays or radium. Treatments which gave many chromosome rearrangements when applied to sperms gave no evidence of effect on the egg chromosomes. This surprising result led Metz and Bozeman to a cytological study of the egg chromosomes, which in turn led, as indicated in previous reports, to the conclusion that lack of movement was probably responsible for lack of susceptibility, and that therefore movement probably plays an important part in the process of chromosome rearrangement. The possible significance of this finding has been discussed previously. To test the hypothesis, two detailed studies have been carried forward in recent months.

One, by Dr. J. Paul Reynolds, has shown, as predicted, that at a stage when meiotic movement begins, i.e., somewhat later than that mentioned above, the egg chromosomes become sensitive or susceptible and give rearrangements in considerable numbers when irradiated. Thus far, therefore, the results support the hypothesis. And the combined results indicate that irradiation during the "insensitive"

stage does not produce incipient "breaks" which lead to rearrangements at a subsequent stage. In other words, there is no evidence here of a delayed effect, such as is found in some organisms. A special study is now being made of details of the process, in the hope of distinguishing between the sensitivities of the different stages when different kinds of movement occur.

The other study represents an attempt by artificial means to render the chromosomes sensitive at a stage when they are normally insensitive. This study is undertaken because of the feeling that if sensitivity can be induced artificially, a more delicate tool will perhaps be available for analyzing the mechanism of induced rearrangements than can be obtained in any other way. Two main factors, instead of only one, will be under control. The task is, of course, very difficult and laborious; but since the material (*Sciara*) appears to be the best material known for the purpose, attention is being concentrated on the problem. Miss M. L. Bozeman has developed a suitable technique for the work and has carried out numerous preliminary experiments, using especially centrifugation in combination with irradiation. Discussion of these experiments will be deferred until the work has progressed farther.

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T. H. MORGAN, JACK SCHULTZ, and VIOLA CURRY, California Institute of Technology, Pasadena, California. *Investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15 to 39.)

As was reported last year by Schultz and Curry, a statistical analysis is under way, in which the attempt is being made to determine, by a detailed classification of the mutants according to their phenotypic effects, whether there is any association between the phenotypic effect of a gene and its locus on the chromosome. Such an analysis of the mutants in the X chromosome has proved so far inconclusive, and the attempt is to be continued with the addition of the mutants of the second and the third chromosomes, in the hope that an increase in the numbers will permit statistical tests to be applied.

The problem is in the meantime being attacked in another way. It has previously been reported that the heterochromatic regions, which furnish a striking example of nonrandom cytological distribution, have as their most striking genetic property the induction and modification of variegation in somatic cells. Cytological evidence has recently been adduced by Kaufman and by Prokofyeva-Belgovskaja for the assumption that regions of this kind are distributed through the chromosomes, although the principal groups are still to be found around the centromeres. For the proper evaluation of the presence of "interstitial heterochromatin," genetic evidence is desirable. It was already known for certain of these regions that genetic effects on the grade of variegation exist. Schultz has now carried out an experiment in which the distribution of these regions throughout the chromosomes might be detected. In the progeny of X-rayed white-eyed males, mated to variegated white-eyed females (inversion white-mottled⁴), suppressors and enhancers of variegation induced by the treatment could

be detected, and these modifiers, when located, would give evidence of the distribution of heterochromatin in the chromosomes. In the progeny of over one hundred cultures, fourteen suppressors and fifty-eight enhancers were found. The localization of these types is now in progress; the results are already of some interest. Seven sex-linked enhancers of variegation have been found, all of which are themselves translocations involving centromeric heterochromatin. In the autosomal group, the most interesting ones are several which are deficient for regions within the sections ordinarily called euchromatic. They differ among themselves in type, but are more extreme in their effects than the loss of a Y chromosome, and there are indications that specific effects, as between different variegation types, are found. It is evident from the high frequency of occurrence of these modifiers that the determination of their distribution on the chromosome is feasible. Since the heterochromatic regions have been distinguished by their lack of any specific morphological effect on the organism (their so-called inertness), the further analysis of these newly discovered genes showing similar effects within the so-called euchromatic regions should throw light on the nature of heterochromatin in general.

In this connection it is of interest to consider various genetical possibilities. Muller and Prokofyeva some years ago suggested as one possibility that the heterochromatic regions might owe some of their properties to their origin as duplications, which could all pair with each other homologously. Thus the heterochromatic regions would owe their confused type of indiscriminate pairing with each other

to their being tandem duplications, and it becomes of interest in this connection to examine the properties of recently arisen euchromatic tandem duplications. To the three previously reported cases—Bar, Hairy-wing, and the Star suppressor of Lewis—a new tandem duplication for the Notch region may now be added (Schultz). This duplication includes the salivary-gland chromosome region 3C₅-3D₆, and was originally described by Gottschewski as a recessive allelemorph of Notch (Confluens) which suppressed the Notch effect. This duplication, like the others previously found, resembles the heterochromatin in the confused cross-pairing between the members of the duplication. There is, however, no especial tendency of the Confluens duplication to be associated with the chromocentral regions. This type of lateral pairing between the members of a tandem duplication, found also in the Bar case by Bridges, has recently been misinterpreted by Hager in the analysis of the double Bar type, where it occurs to an extreme degree in the triplication. He considers that there is merely a swelling present in double Bar as compared with Bar, but it is evident that what he has seen is the lateral pairing.

The phenotypic characteristics of the Confluens tandem duplication have been found to be due to the repetition of the Notch locus. The evidence comes from the phenotype of individuals studied by Schultz and Curry, in which as a result of crossing over between Notch and Confluens only one Notch locus is present although the rest of the duplication still remains. The Notch region has been much studied, and with the array of multiple alleles present, the tandem duplication will be valuable in the further analysis of the region. One of the mutants at the Notch locus, Abruptex, was postulated some years ago by Nasarenko to be a du-

plication for Notch, since it neutralized the Notch effect. Since a duplication of the Notch locus per se causes the Confluens effect, it follows that Abruptex must be something of a different nature. Actually, the salivary-gland analysis of the Abruptex case (Schultz) shows the presence of a small (single band) duplication, just around 3C₇. The suggestion is obvious that the Abruptex effect is a position effect at the Notch locus due to the smaller duplication. A test of the hypothesis is possible by the study of the X-ray-induced derivatives of the larger Confluens duplication: the appropriate small deficiencies derived from Confluens should be of the Abruptex phenotype. Such an experiment has been carried out, and six derivatives obtained: one a reversion of Confluens, three with Abruptex-like bristle effects, and two that are more extreme Confluens. Those that have been analyzed show breaks in this region, indicating that phenotypes like Abruptex, although not allelic to it, can be produced as position effects in duplications of the Notch locus. The picture that emerges from the comparison of Confluens with Abruptex and the Confluens derivatives is one of position effects between the identical members of the duplication, but only at very restricted distances (several bands at the most). The question of the distance over which position effects extend is raised, of course, in the translocations inducing variegation, where the distances may be much greater. Demerec and Sutton have already, in their studies of the white locus, pointed out that the "euchromatic" translocations for the region induce position effects only at very short distances. The question arises whether these are, in fact, to be considered as position effects rather than as intragenic changes.

Evidence indicating that these changes are due to position effect comes from an

analysis of a reversion of the Hairy-wing phenotype to one less extreme (the suppressed Hairy-wing of Curry). In this type the expression is roughly that of a simple duplication for the achaete locus, as if the position effect had been annulled, and what remained were simply the quantitative effect of duplication. The salivary-gland chromosomes of the reverted type show that there has been a small inversion of approximately two bands (1A3-1B1) which has separated the duplicated achaete bands from each other. In other words, the separation of the duplicated loci by a distance of two bands is sufficient to remove the position effect. It follows that we are here dealing with a close-range phenomenon, suggesting that the distance over which this position effect extends may be as little as an interband space. It seems clear that with this restriction of the distances over which position effects extend, the recent attempt (Goldschmidt) to use position effects as the basis of a chromosome theory according to which there are no individual genes, but only a sequence of interacting "chromosome patterns," will end by placing these patterns in essentially the place occupied by the classic gene.

Last year's report contained an account of work by Schultz and Curry on the nature of the heterochromatin of the right limb of the second chromosome, an attempt at a detailed analysis of the properties of that region. The analysis has been continued. It has been shown that the mutants apterous and blot, formerly considered as representing separate loci, are allelic; a fact of interest in terms of wing development, since in one mutant the wing is missing, in the other it is duplicated. New material has been obtained for the rolled locus, which has substantiated the earlier location of this gene between the centromere and the heterochromatic region associated with 41B1. The results of most general

interest, however, are those obtained in crosses of the different rearrangements of this region with *Drosophila simulans*. It was established several years ago by Schultz that *D. simulans* behaves toward *D. melanogaster* as if it contained an extra Y chromosome; for example, variation in the hybrids is suppressed to an extent similar to that encountered in the presence of an extra Y chromosome. The deficiency Minute S10, reported last year to have a more powerful effect on the variegation than any of the other changes in the 2R heterochromatin, permits a further analysis of this difference. Hybrids with *D. simulans* carrying the M-S10 chromosome either die at any early stage of development, or in certain crosses survive as individuals with tumors (melanotic tumors found in the fat bodies) and duplicated organs (legs, antennae, aristae, or wings) or missing organs. Evidently in the hybrids the haploidy for the section included in the second-chromosome deficiency causes an upset of the organization of the symmetries of the imaginal disks. By means of similar crosses with the others of the group of deficiencies and translocations available in this region, this aberrant behavior in the hybrids was found to be the property of a region involving the heterochromatic block and the rolled locus. A study of the progeny from various reciprocal crosses has given information showing that the effects of this region in the hybrids are the results of an interaction with the X chromosome. The *simulans* X, in this as in the usual hybrids with *melanogaster*, appears to increase the viability and the normal appearance of the hybrids. The hybrid males carrying the *simulans* X chromosome show no duplicated organs in the presence of Minute S10, although they still show tumors. The complex of different phenomena can be understood in terms

of a change in the heterochromatin balance between the X and the second chromosomes in the two species. The remarkable fact is, however, that a region whose loss is relatively innocuous within *melanogaster* (arguing from the properties of the deficiency) should effect such profound changes in the hybrids. There is evidence, not yet complete, that the results are to be related to the effects of heterochromatin on the variegation process.

It has been postulated that the role of heterochromatin in the production of variegation is concerned with the process of gene reproduction. During the past year an independent line of evidence has been found to reinforce this view. The process of endomitosis, or multiplication of the chromosomes within the nucleus, has been described by Bauer and by Painter and Reindorp as occurring in the nurse cells of the dipteran ovary. The situation in *Drosophila* has been restudied, with especial attention to the endomitotic behavior of the heterochromatic regions. In agreement with Painter and Reindorp, a series of endomitotic cycles was found: the chromosomes go through the analogues of interphase, prophase, metaphase, and telophase. The prophases in the larger cells resemble somewhat the salivary-gland-type nuclei, being somatically paired, but they subsequently undergo a contraction and falling-apart which results in the formation of a cluster of short metaphase-like chromosomes. So far the picture is a conventional one. The heterochromatic regions behave differently. They are condensed and more deeply staining than the euchromatic regions in the interphases, and have a structure somewhat like that of the chromocenter in the salivary-gland chromosomes. In the medium-sized (32-ploid) nurse cells, where the somatically synapsed euchromatic regions show a definite increase in the number of strands, at

prophase, the heterochromatin is condensed, and still appears to be approximately four-stranded. This would suggest that the heterochromatin is reproducing at a slower rate than the euchromatic sections.

This possibility has been studied in females having extra Y (completely heterochromatic) chromosomes. The Y chromosome goes through the same changes as the other heterochromatic regions during the endomitotic cycle. Like these it also divides at a slower rate. At the maximum size of the nurse cell, either four or eight Y's are seen, bipartite elements, associated at the centromeric regions. Similarly, in the females containing two Y chromosomes, eight to sixteen such bodies are seen in the largest cells (512-ploid). The question of growth in volume of the individual heterochromatic bodies is not yet decided: it cannot be much more than twofold. Other tests with deficiencies of heterochromatin in different chromosomes give evidence that the behavior of the Y's is not due to a balance between the different heterochromatic regions, but to a characteristically slow rate of reproduction of these chromosomes.

These data have many implications, since they give evidence that the different tissues vary in the constitution of their nuclei, owing to differential rate of reproduction of the parts of the chromosomes. Various speculations are possible, according to which the embryological differentiation of the tissues may be conditioned by the differentiation of the nuclei. These speculations now have a concrete basis. The relation of these data to the effects of the heterochromatic regions on variegation is also of interest: translocation to those regions, whose reproductive rate in the nurse cells is slower than that of the others, induces a variegation which in many cases simulates a decreased gene ac-

tivity. What we have here is apparently a link between the processes of gene reproduction and gene function, such that genes translocated to heterochromatin may be postulated to assume the heterochromatic character and reproduce more slowly. This is, of course, precisely the type of change observed in the salivary-gland chromosomes of these variegated races: an increase of the nucleic acid content of the bands, followed by their assumption of a heterochromatic character, and their "disappearance." Thus the mechanism of variegation, previously postulated on the basis of the nucleoprotein metabolism of the salivary-gland chromosomes—namely, a change in the mode of reproduction of the genes translocated to heterochromatin—finds a new basis in the reproductive behavior of the heterochromatin itself. In the specific case of the nurse cells, the delayed reproduction may result from a failure to move apart due to the lack of a stimulus from the spindle-forming mechanism; or the delay may be associated with the special role of these regions in the nucleic acid metabolism of the nurse cell, which is particularly active.

The role of the heterochromatic regions in the nucleic acid metabolism of the cytoplasm and their relation to the nucleolus have suggested that heterochromatin might contain the ribose type of nucleic acid hitherto regarded as absent from the chromosomes. This possibility seemed a point of cardinal importance both for the general chemistry of the chromosomes and for the special question of the localization of chemical differences in specific regions of the chromosomes. Differences in the type of protein of the different regions have already been suggested by Caspersson, but the presence of the ribose nucleic acids is difficult to demonstrate where the desoxyribose nucleic acids also appear. It seemed possible, following

Brachet's attempt with amphibian chromosomes and Kunitz' preparation of the enzyme in crystalline form, that the enzyme ribonuclease, which is supposed to attack a specific linkage in the ribonucleic acids, might be used to test for their presence in the salivary-gland chromosomes.

Experiments of this type were carried out with a preparation of the crystalline enzyme kindly supplied by Dr. Kunitz. Salivary-gland chromosomes were fixed in 45 per cent acetic acid and carried through alcohol vapor into 95 per cent alcohol, then down through water into the enzyme solution. Controls were either in distilled water or in inactivated enzyme at the same pH. Staining was carried out in acetic-orcein, followed by fast green. The fast-green counterstain was found in special experiments to be useful in distinguishing between the higher proteins and those like the protamines, since it combines with the former and not with the latter. Fast-green-orcein stained chromosomes have almost black (red plus green) bands, green interband spaces, and non-staining proteins within the "capsules." Digestion with the ribonuclease removes first the fast-green-staining component (protein), then the orcein-combining components (nucleic acids), leaving a non-staining structure with green bands. In the extreme cases a mass of nonstaining material, probably protein, is left in the nucleus. Sperm are unaffected by such treatment; thymus cells of the calf are digested only slightly. The picture is one of a "cement substance" being attacked by the enzyme, a picture rather unexpected and waiting for its definitive interpretation upon the further chemical analysis of the action of the enzyme. It is tempting to consider that if the bond attacked by the enzyme turns out to be specific to the ribose nucleic acid molecules, it will have been shown that the skeletal structure

of the chromosomes is a ribose nucleic acid compound: a result fully in line with the hypothesis already developed that the units of synthesis are the ribonucleo-proteins.

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For nearly a century science has considered living species to be somewhat more rigidly specific, in their internal chemistry, than they really are. A period of rather far-reaching readjustment of concepts has now begun. Physicochemical principles, together with the evidence most recently obtained through comprehensive experiments with laboratory animals, clearly show the reality of the influence of food adjustments upon the body's internal environment. What may be called the principle of the nutritional improbability of the normal has been statistically established. The effort now is to ascertain to what extent this can be explained in terms of the influence of the chemistry of the food upon the chemical composition of the normal body. For the reasons explained in previous reports, three of the chemical factors in the general problem have promised results of special significance: calcium, riboflavin, and vitamin A.

The experiments with calcium have been planned in two main series. The first of these had as its starting point diet A, which is of only slightly more than minimal adequacy in calcium and vitamin A content, with moderate amounts of riboflavin and protein, and generous margins of the other known nutrients. It contains 0.19 to 0.20 per cent of calcium in the food solids and is in many ways representative of the food of a large proportion of the human race, and of typical American families. Raising the calcium level of this dietary has resulted in higher

percentages of body calcium and enhanced nutritional well-being throughout a longer life span. In both these respects the plateau of optimal response has been reached with a calcium intake about three times that of minimal adequacy. In the second series of experiments upon the influence of the level of calcium intake, the basal dietary was nearly twice as rich in calcium, riboflavin, and vitamin A, and contained somewhat more protein of slightly higher nutritional efficiency (better balanced amino acid composition). During the past year the data of this series have been completed and published. Here it is found that stepwise increase of the calcium-intake level, from 0.34 to 0.48 and 0.64 per cent of the food solids, respectively, has resulted in successive increases in percentage of body calcium at a given age, the difference thus induced being one-tenth to one-twelfth at the period of most rapid growth and about one-thirtieth at full maturity. The present workers are indebted to conferences with the late Dr. T. Win-gate Todd for cogent expressions of his view that this extra body calcium may be a very important asset in the vicissitudes of human life.

In the experiments with riboflavin, as in those with calcium, it is found that the zone of increasing benefit with increased level of nutritional intake, above that of simple adequacy, is relatively wide. To a less extent than with calcium, however, can the beneficial effects of the higher intakes of riboflavin be explained in terms

of increased body content of the substance. Hence the question arises whether, when the riboflavin content of adult tissues no longer increases measurably in response to increased nutritional intakes, these higher intakes may nevertheless improve the body's internal environment in some other way, inasmuch as the higher intakes seem to result in more vigorous offspring. Or, are present methods of nutritional experimentation dealing with differences which chemical analysis *in vitro* does not yet detect? By a new analytical method developed for the purpose, further light on this question is now being sought through analyses of offspring at earlier ages, as well as of adult animals from different nutritional backgrounds.

In the analogous study of vitamin A, there has been completed and published a preliminary series of determinations in the muscles of animals which had been fed different levels (adequate and more liberal) of this vitamin. Here there appears to be a very slight difference, barely demonstrable by present methods. In the liver, however, the difference due to diet is being found to be even larger than was hitherto supposed; and an age difference is also being found which appears highly significant in view of the indications that the requirement for this vitamin increases with age and that subclinical shortages are much more frequent among human adults than was hitherto supposed.

Both the riboflavin and the vitamin A experiments deal with differences which nutritional chemistry now shows to be very significant for higher health and for longer periods of fully effective adult life. It is hoped to continue these two

lines of experimentation. The findings should help to clarify the new concept of a hitherto unsuspected degree of flexibility in the chemical factors of the internal environment. We now see that each man, as he decides from day to day what foods to eat and in what proportions, is functioning (whether he knows it or not) as a biochemical engineer of his own life process; and it is important to know more accurately how much this affects his efficiency and social value.

The generous and efficient service of those who have collaborated in the work here reported, whether as research assistants or as volunteers, is gratefully acknowledged.

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DIVISION OF HISTORICAL RESEARCH

Cambridge, Massachusetts

A. V. KIDDER, *Chairman*

The devastating ill wind which the present international situation has set blowing across the world has had at least one happy result in bringing the nations of the Western Hemisphere closer together. We of the United States and the peoples of Latin America, being equally the cultural offspring of the Old World, have naturally sought overseas for intellectual, spiritual, and artistic contacts; both we and they have confined our foreign travel almost exclusively to Europe. The result has been a most lamentable ignorance of each other's countries and of each other's ways of living and thinking. Americans (to use, for want of any other, a term whose calm assumption of sole occupancy of two continents is quite reasonably distasteful to our southern neighbors) are even more remiss in this regard than citizens of the Latin republics. So it is well that, albeit tardily, there have come realization that we share with them a common destiny, and recognition of the fact that only through fuller knowledge can there be achieved the mutual understanding and mutual respect necessary for a united stand in defense of New World ideals.

Scientific institutions can play a most effective part in fostering friendship between the Americas. They have no political objectives, they seek no commercial advantage. Their research workers import nothing but a great curiosity about nature and man, they export only facts. Their findings are given freely to all who wish to make use of them. And, most important of all, they are coming to cooperate more and more closely with governments and universities for attack on problems of common interest. It is impossible to exag-

gerate, to cite the most outstanding example, the contribution to good will toward the United States that has been made by the Rockefeller Foundation through its medical researches.

The Carnegie Institution of Washington has for many years sponsored studies in Latin America dealing with almost every major branch of the physical, biological, and social sciences. The Institution's Division of Historical Research has, during the past two decades, devoted its major effort to work in Middle America. As stated more fully in earlier reports, its aim has been to gain knowledge of the pre-Columbian civilizations, of colonial and republican history, and of life in the modern societies formed by the welding together of Indian and European elements. Only by thus combining researches in archaeology, documentary history, and ethnology, together with supplementary studies of the environment, can adequate understanding, it is felt, be had of present-day conditions.

In its work in the Middle American republics, the Division has operated under governmental contracts, and has cooperated actively with native scholars. Two of its investigators are Mexican citizens; another is a Guatemalan, as is its staff artist. In Honduras, the Division has been entrusted with the expenditure of the funds which, dollar for dollar, the government of that country has matched with those of the Institution, for the excavations at Copan.

In addition to its purely scientific objectives, the Division has striven to preserve and make permanently available for scholars, students of art, and the native and

traveling public the most important architectural and sculptural remains of the ancient Maya. At Chichen Itza in Yucatan, at Quirigua in Guatemala, and at Copan in Honduras, work of this type has been carried on, generously aided by grants from the Carnegie Corporation of New York.

During the period covered by the present report (July 1, 1940, to June 30, 1941) archaeological investigations went forward in Mexico, Guatemala, Honduras, Salvador, and Nicaragua. Drs. Redfield and Tax continued the ethnological survey of highland Guatemala; Sr. Villa, that of Maya-speaking tribes in Mexico. Mr. Scholes and his associates of the Section of Post-Columbian American History worked in Washington on materials gathered during former years. Dr. Sarton brought nearer to completion the third section of the *Introduction to the History of Science*, covering science and learning in the fourteenth century.

The Division and American scholarship suffered an irreparable loss in the death, on January 26, of Dr. Manuel J. Andrade. Born in Spain in 1885, Dr. Andrade was educated at the Instituto Regional of Coruña, and came as a young man to the United States, where he held various positions as a teacher of Romance languages. Becoming interested in the scientific aspects of linguistics, he studied under Dr. Franz Boas and received the doctorate from Columbia University in 1929. In the following year, he accepted a joint

appointment as Associate Professor at the University of Chicago and Staff Investigator of Carnegie Institution. Half Dr. Andrade's time was devoted to teaching advanced students in linguistics, and half to field work and research on the languages of the Maya stock. He made many trips to Mexico and Guatemala, amassing enormous amounts of material concerning Yucatecan Maya, Huastec, Quiche, Tzutujil, Cakchiquel, Pokoman, Mam, and other tongues. In the course of this work, he developed remarkably effective means for the mechanical recording of speech. At the time of his death a compendious monograph on Yucatec was nearly complete. In this work, which is being made ready for publication by his former secretary, Mr. S. L. Bradshaw, Dr. Andrade utilizes new methods of linguistic analysis. It is believed that the work will not only be of great value to Maya students, but will also constitute a highly significant contribution to linguistic science. Dr. Andrade's materials on the other Maya languages were collected with such painstaking accuracy and recorded with such characteristically meticulous care that they can readily be utilized for continuance of the research which he so brilliantly inaugurated.

The only change in the personnel of the Division has been caused by the much regretted resignation of Mrs. Walter M. Edwards, who since 1931 served faithfully and efficiently as Division Accountant. She has been succeeded by Mrs. Douglas Tepper.

ARCHAEOLOGY

As stated above, archaeological work has been done, during the past year, in five Middle American republics.

In Yucatan, Dr. Sylvanus G. Morley excavated at the ruins of Uxmal, clearing a masonry platform on which were frag-

mentary remains of a number of stelae, and assembling the pieces for study and photography. He also recovered several hitherto missing bits of two large stone rings (comparable in function to basketball goal rings) which had fallen from op-

posite walls of a ball court. The special interest attaching to these rings, parts of which have been known for many years, is due to their bearing very important calendrical inscriptions.

Mr. Joseph Lindon Smith, outstanding painter of ancient sculptures, particularly those of Egypt, repeated his visit of 1940 to Yucatan, where he produced a further series of canvases of reliefs and carvings in the round. As in 1940, Mr. Smith presented these invaluable records of Maya art to the Carnegie Institution, which, in turn, will distribute certain of them to museums in Mexico and the United States.

Dr. George Brainerd was in Yucatan until February, finishing his observations on the pottery collected during past years from various parts of the Peninsula. Since then, he has been at Division headquarters in Cambridge, preparing a report on Yucatecan ceramics.

In Guatemala, Mr. A. Ledyard Smith excavated in one of several narrow, rectangular, earth-walled enclosures occurring at the Kaminaljuyu site. Although their function was unknown, it was suspected that they might be remains of ball courts. Trenches dug by Mr. Smith proved this to have been the case. The Chairman also worked at Kaminaljuyu, making a surface study of its nearly two hundred mounds. Mr. Robert E. Smith was in Cambridge for about half the year, preparing the final report on the pottery of Uaxactun. On his return south in January, he resumed direction of the Guatemala office and laboratory.

In Honduras, Mr. Gustav Strömsvik, assisted by Mr. Robert F. Burgh, Mr. Arthur W. Wheelwright, and, as a volunteer, Mr. Leonard J. Currie, Fellow of the Harvard Architectural School, completed the excavation and repair of the temples adjoining the Copan Ball Court. He also reset the displaced elements of the so-called

Venus mask panel, which surmounts the Jaguar Stairway. During the season, Mr. Strömsvik continued the installation of specimens in the Copan Museum; and Mr. Burgh aided the local authorities in completing an aqueduct which will, for the first time, provide the town with a supply of running water.

During the year, the Division has extended its archaeological investigations to Salvador and Nicaragua. In the former country, excavations west of the city of San Salvador were inaugurated in 1940 by Mr. John M. Dimick under the auspices of the Middle American Research Institute of Tulane University. At the close of that season, the Division was invited by the University, at Mr. Dimick's suggestion, to cooperate; and when reorganization of the Middle American Research Institute compelled its withdrawal from active field work, Mr. Dimick, who finances and directs the undertaking, requested the Division to continue its association therewith. This offer, giving opportunity to keep in close touch with research in a highly important and hitherto next to unknown area, was gladly accepted, and all members of the Division staff who were in Central America profited by visits to the excavations and by discussion of the problems involved. The work has revealed a most interesting sequence of unexpectedly large buried structures, study of which is yielding invaluable information as to architectural and ceramic developments.

In Nicaragua the season's activities demonstrated anew the fact that, in archaeology, the unforeseen always happens. Mr. Francis B. Richardson went to Nicaragua to examine, as part of his study of Middle American sculpture, certain carved monuments mentioned in the literature. In preparation for his visit he had read all available accounts of previous exploration

and had noted references to human footprints found many years ago in a deeply buried volcanic stratum just west of Managua. On arrival at Managua, Mr. Richardson made inquiries regarding the footprints, and learned that quarrymen had recently uncovered new examples. He was taken to the site, recognized the importance of the tracks, and undertook a series of excavations which, occupying the entire season, effectually prevented any attention's being given to the sculptured monuments. The report of Mr. Richardson is included among the summaries of work which follow.

HONDURAS

G. STRÓMSVIK

The work of excavation and repair at the ruins of Copan, Honduras, which has been in progress since 1936, was continued during the past winter. Mr. Strómsvik was assisted by Mr. Robert F. Burgh, Mr. Arthur W. Wheelwright, and Mr. Leonard J. Currie. The major activities of the season were completion of repair of the two temples at the Ball Court, and re-setting of the upper elements of the Jaguar Stairway. Mr. Burgh accomplished a thorough survey of the minor ruins in the valley. As in former years, the Government of Honduras cooperated most effectively, providing all labor, including five master masons specially sent to Copan, and transporting, without cost to the Institution, supplies from the railhead at Chiquimula in Guatemala.

The temples at the Ball Court were large and handsome structures with elaborately ornamented façades flanking the two sides of the court's playing alley. Their massive vaults had collapsed, filling and covering the lower parts of the several chambers of each temple with stone and rubble. In 1940 this was cleared away and

the still standing outer walls were solidified by the method developed by Messrs. Morris and Strómsvik in their work on the Temple of the Warriors at Chichen Itza and followed in all subsequent repair operations. Solidification is made necessary by the fact that the original adhesive qualities of the ancient lime or mud mortar have more or less been destroyed through action of percolating rain water, with such weakening of the masonry as to render walls incapable of standing for any length of time, once the supporting debris has been withdrawn. In such cases a wall is cleaned and photographed, and the cut stones of the outer veneer are numbered and removed. If the hearting is found in bad condition, it also is taken down and rebuilt with fresh lime mortar; but if sound, it is allowed to stand and the facing is relaid in cement, each stone occupying exactly its original position. Finally, the wall is capped with cement to prevent further entrance of water.

During the past season the inner walls of both temples were accorded the above treatment. Of the East Temple, the south end, including the vaults of the south and southeast rooms, was rebuilt to its former height. This restoration was particularly desirable as no example of the interesting and highly typical Maya corbeled vault remains standing at Copan. It was possible because the original stones, though fallen, were still available; and it could be done with confidence, as a sufficient number of the lowermost stones of the vaults were found in place to allow accurate calculation of their angle and height.

The wide doorways of this and other Copan temples had been spanned with heavy beams, whose decay, incidentally, was one of the major factors in bringing about the collapse of the upper walls. In the restoration, the lintels were made of reinforced concrete cast to the size and

shape of their wooden prototypes. The façades over each doorway had been decorated with sculptured panels representing a gigantic and highly conventionalized parrot with protruding head and claws. Since the depictions had been composed of dozens of relatively small carved stones tenoned, like a mosaic, into the wall, and since these elements had been broken and scattered when the façades fell, and some had been carried away in recent times, the correct reassembling of the panels was so uncertain that the spaces occupied by them have, for the time being, been left vacant. The stones have been carefully numbered and preserved, however, and it is possible that further study will result in a satisfactory solution of this oversize jigsaw puzzle.

The West Temple was cleared and its walls reset as high as the second course above the medial molding. Farther up it was not possible to go because this temple, lying nearer to the road than does its mate, had largely been robbed of cut stone for use in building the modern town of Copan.

In connection with the work on the temples, the badly displaced facing of the terraces and steps surrounding the north end of the Ball Court proper was taken down and relaid. This produced a proper setting for Stela 2, which stands upon the north platform, and links the latter with the structures bordering the whole complex. Also, to the south of the East Temple, the lowest terrace of the high Pyramid 26 was rebuilt, thus making clear the relation between the Hieroglyphic Stairway, mounting that pyramid, and the Ball Court. During this operation there were recovered and replaced certain hitherto missing elements forming the base of the Hieroglyphic Stairway's north balustrade.

A second major undertaking was con-

cerned with the Jaguar Stairway in the East Court. The lower part was repaired in 1938, but this increased the necessity of completing the construction, including the magnificent Venus mask panel (so called because of large hieroglyphs of that planet on either side of the mask). The task involved the removal of the existing remains, the building of a solid masonry foundation, and the replacement of the upper terraces, the stairs, and the mask itself.

While work was under way in the East Court, opportunity was taken to repair the vaulted drain which runs eastward under Mound 19 and opens on the river front. Former excavators had dug a large cut into the mound, causing a serious cave-in of the fine example of Maya vaulting in this drain. The interior was rebuilt, and the steps of Mound 19 were replaced as far as possible without reconstructing the whole stairway.

In 1939 some inscribed stones came to light around the roots of the giant ceiba tree standing on the east end of the mound of Temple 11; on further investigation blocks forming an almost complete hieroglyphic panel were extracted from beneath the enormous tree. This panel, from the north side of the east entrance, corresponded in size to others previously known to flank either side of both the north and south doorways of the temple. During the past season search was made for the companion panel at the south side of the east entrance. It was found partially crushed, but all pieces were present, constituting the only complete hieroglyphic panel recovered from Temple 11. This structure had four doorways, each framed by two panels, each panel containing from 15 to 18 glyph blocks. Thus the eight texts comprised about 140 glyph blocks, many more than any other temple in Copan can boast. For this reason it has

been decided to call it "The Temple of the Inscriptions." The panel found in 1939 was removed to the Copan Museum, as it could not well be replaced without destroying the giant ceiba; the one discovered this year was reset in its original location.

In 1940 the opening of a drain was found under the west end of the Acropolis. This solved the puzzling problem of how disposal had been effected of the great amounts of water which fell each rainy season on the Ceremonial Court, the Middle Court, and the Court of the Hieroglyphic Stairway. This season the drain was excavated, with great difficulty as it measured only 45 by 50 cm. and was completely full of hard-packed refuse. It proved to have been built of three tiers of well fitted masonry, laid on a paved floor, and covered with wide capstones. Several of the latter had broken and tipped downward into the drain, further hampering the work of clearing it. A stoppage had taken place at the far end, apparently when the west side of the Acropolis fell into ruin, and most of the many potsherds found in the passage occurred there; among them was a complete water jar shaped much like those used in the valley today. The caved-in entrance of the drain was repaired, and the outlet cleared to permit free flow for the water that has hitherto accumulated in the Court of the Hieroglyphic Stairway. During the digging of the escape ditch through the high pile of debris fallen from the Acropolis, two skeletons were encountered, both apparently of young men. Although the bones were in the last stages of decay, the teeth were well preserved; the six upper front teeth of each skeleton were inlaid with jade.

Repairs were made of several sculptures: a fine double-headed monster at the west end of the Court of the Hieroglyphic Stair-

way, Altars H' and I' at the south end of the West Court, and Altar G in the Ceremonial Court.

Mr. Burgh devoted the major part of the season to completion of the map locating the outlying ruins of Copan. The area covered was about 18 sq. km., within which the ruins, the Copan River, minor drainages, roads, and settlements are shown at a scale of 1:10,000. Control was established by a system of triangulation on the higher hills, and a number of the stations were marked by permanent stone monuments. The meridian was determined by astronomical observations, the datum by barometric readings. Mapping of ruins was done with a plane table. The majority of the sites were pyramids, terraces, and courts bordered by mounds; the rest were clusters of small mounds. All sites, however small, were drawn to scale, and the various types are identified by conventional signs on the map. Sites were numbered serially within the areas designated by Dr. Morley in plate 3 of *The inscriptions at Copan*.

Six ruins were mapped at a scale of 1:500, with a contour interval of 0.5 m. No excavation was attempted at these sites, save at no. 2 in area 9, where a large, handsomely cut stone in the center of the court was overturned to ascertain whether hieroglyphics were present on any of the buried faces. None was found.

Sketches at a scale of 1:1000 were made of 26 ruins, with cross sections and notation of the presence or absence of cut stone and sculpture.

The commonest type of outlying structure at Copan proved to be a court bordered by mounds on three, or sometimes on all four, sides. No system of orientation was evident. Apparently these sites were residential, the mounds, rubble-filled and faced with cut stone, serving as platforms for dwellings. They are not all

contemporaneous, and as it is likely that some of the larger mounds served for many consecutive occupations, they may be expected to show many alterations and enlargements. Occasionally, a single large mound was accompanied by many lesser ones, perhaps platforms for smaller houses.

There were several unusual structures. The great court of Ostuman, about 2.5 km. west of Copan Village, was doubtless a complex of religious structures. To judge by the absence of sculpture, it was earlier than the Main Group. On El Plan de las Mesas, a high hill northwest of Copan, are several structures of curious shape built of roughly quarried stone. The most westerly is a round tower, 8 m. in diameter and 1.50 m. high. One fragment of rude sculpture suggests a later date than the primitive masonry would imply. Just 0.5 km. east of the Main Group, in the midst of a dense cluster of plazas and mounds, there is a causeway about 10 m. wide throughout its length and about 1 m. high. If this was a roadway to the Main Group, as seems likely, there is no positive trace of its westward extension.

It cannot be assumed that sites with roughly hewn stones are earlier than the others, because it is possible that they represent the rubble interior of mounds from which the better-cut stones were removed for use elsewhere.

Excavation was done at Site 8:16, a refuse area in a gully east and north of Stela 6. No house remains were encountered, but occupational debris was found, its maximum depth being 2 m. Two levels of occupation were in evidence. The upper, a mixed stratum varying in depth from 20 to 50 cm., was contemporaneous with the Old Empire remains in the Main Group. In this level were three burials, all badly decayed. Between the upper and lower levels was a thick white deposit, the remains of a plastered courtyard, or

perhaps a house area from which the stones had been removed for use elsewhere. The lower deposit had a maximum depth of 1.50 m. It apparently long antedated the upper level, as the pottery was of early types, much with "Usulutan" (wax process?) decoration, chiefly on tetrapod plates. Sherds of ollas were characteristically ornamented with a band of clay pinched on around the girdle. A few sherds of stuccoed ware were found. Hundreds of small incense burners, 6 to 8 cm. high, came to light, whole or fragmentary. They were decorated with punctate designs. Most surprising was a sherd of polychrome ware at the bottom of the deposit, 2 m. below the surface. It was red and black on yellow, and technically superior to any of the later wares. Snailshells occurred by the thousand, and there can be no question that this was a kitchen midden.

YUCATAN

S. G. MORLEY, G. BRAINERD

Dr. Morley remained in Yucatan throughout the year, engaged in completing the manuscript of his history of the Xiu family, founders of the city of Uxmal. In February he spent a fortnight at Uxmal with the following objectives: (1) the assembling of the broken and, in some cases, fragmentary stelae on the stela platform about 150 m. west of the northwest corner of the Monjas Quadrangle; (2) further excavations in the Ball Court for the purpose of locating still missing fragments of the two rings, each of which has a hieroglyphic inscription on its two sides; (3) the assembling and repair of the several hieroglyphic panels which formerly faced the three platforms in the so-called Cemetery.

The stela platform was discovered by Mr. Frans Blom, of the Middle American Research Institute of Tulane University of

Louisiana, in 1932 during an expedition undertaken by that institution to obtain data for the reproduction of the North Range of the Monjas Quadrangle at Uxmal for the Century of Progress in Chicago the following year.

Sixteen stelae, all broken, were found on the platform. Their several fragments were fitted together and arranged for photographing; all but one were found to be sculptured. Of these, fourteen are carved on the front only, and the remaining monument, of which only two pieces were recovered, is sculptured on all four faces. The stelae vary in height, including the plain butts, from 1 to 5 m., and formerly stood in three or four rows across the back (north) side of the platform, all facing south. The stela platform is about 20 m. square and from 1 to 2 m. high, depending on the inequalities of the terrain. Along its east side is a lower terrace about 5 m. long, though the platform would seem to have fronted south, since the stelae all faced in that direction. Thirty-eight monolithic columns or truncated cones were also found, varying in height from 30 cm. to 1.60 m., and three miscellaneous sculptured stones. The inscription on one of the stelae surely begins with the day 12 Ahau; if this day corresponds to a katun ending, the most plausible assumption, the two most likely Long Count positions are: 10.17.0.0.0 12 Ahau 3 Yax (A.D. 1165), and 11.10.0.0.0 12 Ahau 3 Cumhu (A.D. 1421), the former being much more probable on historic grounds.

The investigation at the Ball Court was undertaken in the hope of finding additional fragments of the inscription on the rings which had been tenoned into the walls on the two sides of the court. This inscription is exceedingly important, as shown by Dr. Morley in 1918 (*Year Book No. 17, 1917-1918*, p. 273n.), since it may well record the day on which the Maya

officially adopted the significant calendric change of shifting the positions of the days in their month one day forward. Excavations were carried out to a distance of 3 m. on each side below the former position of each ring, and to the original floor level of the court. Three additional fragments of the east ring and five of the west ring were recovered.

Six fragments of the east ring have been found: (1) the part still tenoned into the wall; (2) a fitting section found by Dr. Morley in 1918; (3) a section found by the caretaker at Uxmal sometime between 1918 and 1923; (4) a section which fits no. 3, found by Dr. Morley during the current season; (5) and (6) two small flakes also found by Dr. Morley this year, which fit none of the other pieces.

Six fragments of the west ring have also come to light: (1) the part still tenoned into the wall; (2) and (3) sections found this year which not only fit together but also fit the section still *in situ*; (4) and (5) sections also found during the current field season which, though fitting each other, do not fit any other sections of the west ring; (6) a small corner which fits nowhere, also found this year.

Of the epigraphic material presented by the new fragments, the most important is the repetition of the day 12 Ahau, preceded by the winged-Cauac variant of the tun sign. This decipherment is certain and tends to corroborate the probable occurrence of the same day on another section of the east ring, where it follows either a Tun 17 or a Tun 18, also represented by the winged-Cauac variant of the tun sign.

The hieroglyphic panels on the facings of the three low platforms at the Cemetery were in danger of becoming lost. Small flakes of these had been broken off by the action of milpa fires and lay scattered about. These were cemented back into place and a rough attempt was made to

assemble the blocks of the three platforms in their original position. Further work should be undertaken here in order to prevent the loss of this important hieroglyphic inscription.

In addition to the foregoing work, the whole south side of the Cemetery was cleared of bush and there was exposed the original architectural scheme of this misnamed group—a court surrounded by buildings on three sides and a high pyramid and temple on the north side, the enclosure being entered by an arcade passing through the middle of the building on the south side.

Dr. George Brainerd, who was at Chichen Itza during the past field season (1940), stayed in Yucatan during the summer, fall, and early winter, returning to the United States in February of this year. He devoted all his time to a study of the ceramic material recovered by the Institution during the seventeen years of the Chichen Itza Project.

Mr. Joseph Lindon Smith was with Dr. Morley at Chenku near Merida for three months. He accompanied Dr. Morley to Uxmal and made a number of oil paintings there. He also spent ten days at Chichen Itza working on another canvas, and the rest of the time copying sculptures in the Museum of Archaeology and History at Merida.

Mr. Smith returned to the United States early in April, and Dr. Morley sailed from Progreso to New Orleans April 12.

GUATEMALA

A. V. KIDDER, R. E. SMITH, A. L. SMITH

The Guatemala City office, administered by Mr. R. E. Smith, continued to serve as headquarters for the Division's activities in Central America and for those of field workers from other institutions. To the latter it is often possible to be of assis-

tance in supplying advance information regarding the country and as to customs and immigration regulations, in obtaining permits and contacts with government officials, and in providing storage and laboratory facilities. The office is also often called upon to give help to travelers who wish to visit regions off the regular tourist routes.

Mr. R. E. Smith returned to Guatemala in January, where he and Mr. A. L. Smith have continued work on their joint report on the excavations at Uaxactun. Mr. Tejeda, staff artist, spent two weeks at Copan, making paintings of the finer pottery vessels recovered by Mr. Strómsvik during recent years. He made other paintings of vessels in private collections in Salvador. At the office he drew and painted pottery excavated by Mr. A. L. Smith at San Agustin Acasaguastlan in 1940, and by Dr. Mary Butler, working under a grant from the American Philosophical Society, in Alta Verapaz. It is impossible to exaggerate the beauty and the meticulous accuracy of Mr. Tejeda's reproductions of material of this sort.

By courtesy of Governor W. Cameron Forbes, Chairman of the Institution's Board of Trustees, Dr. Kidder was able to accompany him on a trip to the Bay Islands, off the north coast of Honduras. Information was obtained as to prehistoric sites on the islands which it is hoped may eventually be investigated by the Division. Governor Forbes and Dr. Kidder later flew to Copan to inspect the work of Mr. Strómsvik. Dr. Kidder, after visits to Mr. Dimick's excavations at Campana San Andres in Salvador, and to those of Mr. Richardson in Nicaragua, spent two weeks on a study of the great archaeological site of Kaminaljuyu in the outskirts of Guatemala City.

Kaminaljuyu had been mapped by Mr. T. R. Johnson and Mr. E. M. Shook in

former years, and excavations had been made in certain parts of the site, but a thorough surface examination of its two hundred or more mounds had not previously been undertaken. It revealed much of interest regarding the grouping of the mounds. In particular, there were noted at least eight long, narrow constructions whose parallel sides suggested that they might be ball courts, but which lacked the open or expanded ends characteristic of all such courts which had hitherto been noted. To ascertain their nature, Mr. A. L. Smith ran a series of test trenches in one of them, finding a pair of tenoned stone parrot heads on opposite sides at the middle and evidence that there were sloping benches on either side of a playing alley. The latter indications, together with the fact that tenoned serpent or parrot heads have been found in similar positions in ball courts at Copan, San Agustin Acasaguastlan, and San Pedro Pinula, renders it certain that most, if not all, of the Kaminaljuyu structures served that purpose. One or more of them will be more fully examined in the near future.

SALVADOR

JOHN M. DIMICK

During the past field season, Mr. Dimick, assisted by Mr. Stanley H. Boggs, continued the intensive study of the great archaeological site of Campana San Andres. The ruins are situated 32 km. northwest of San Salvador in the fertile, bowl-shaped, and mountain-fringed valley of the Rio Sucio. Although thorough exploration has not been undertaken, mounds are known to be scattered more or less thickly over the valley floor, an area approximately 48 square miles. The most imposing group, perhaps the religious and administrative center of the entire aboriginal settlement, lies near the middle of the

valley on the west bank of the Sucio. Here excavations have been carried out with the generous permission of Don Francisco Dueñas, the proprietor, who did everything possible to facilitate the work.

The principal group consists of a great plaza roughly 200 m. north to south and 140 m. east to west, surrounded on three sides by mounds of various dimensions and on the south by an elevated court (over 6 m. above the plaza) which in turn is partially enclosed by ruined structures. The largest of the latter, Structure 1, almost closes the south side of the elevated court, and Structures 2, 3, and 4 are in alignment along its eastern edge. Small excavations were made for pottery and architectural details throughout the group, but the greater part of the expedition's time was spent in careful exploration of Structures 1, 2, 3, and 4, and one mound (Structure 8) located on the valley floor just south of the southeast corner of the elevated court.

The excavations have disclosed evidence of aboriginal human occupation over a long, but as yet undetermined, period of time. The earliest remains, in the form of pottery and artifacts, were found in the upper 50 cm. of a layer of soil forming an early valley floor. This occupational level was covered by a 25-cm. layer of sterile volcanic ash. Subsequently, the development of the principal group took place. The earlier stages of the growth of the elevated court are indicated at present only by plastered floors encountered above the ash layer and by a stairway in Structure 1. The floors were exposed by a deep test pit in the center of the court; the stairway by a trench into the lower part of Structure 1. Well above the early court floors another floor was found, upon which were built the imposing pyramidal Structures 1, 2, 3, and 4. That the pyramids were crowned by temples may be postulated,

although positive evidence is still lacking. One of the outstanding architectural features of Campana San Andres is the fact that, with a few exceptions to be mentioned later, the pyramids and court foundations are entirely of mold-made adobe blocks averaging in size 62 by 24 by 17 cm. Laid carefully in courses, these formed a very solid construction of uniform strength. All exposed surfaces were finished with a smooth coating of excellent lime plaster, which, despite its hardness and good quality, was frequently renewed on court floors and pyramids.

Structure 1 is a nearly equilateral pyramid, which rose in narrow vertical-walled terraces, probably eleven in number, to a height of 15 m. There was a broad projecting stairway on the north side. The pyramid corners and the edges of the terraces and steps are slightly rounded, and the pyramid as a unit is a splendid example of aboriginal architecture. Structures 2, 3, and 4, arranged in an orderly manner along the east side of the court, are very similar to Structure 1 but smaller.

Another building phase followed the erection of Structures 1, 2, 3, and 4. This mainly consisted of raising the whole elevated court level by 4 m. to its present height, thus burying the lower terraces and steps of the existing structures. The labor involved in this task may be appreciated more clearly when one considers that at least 600,000 adobe blocks were made by hand and transported by man power to the building site to fill the elevated court, conservatively estimated at 15,000 cu. m. volume.

Subsequent substructural renovations took place, some merely frontal additions, others burying more of Structures 1, 2, 3, and 4. New forms of decoration were brought into use—balustrades on stairways, terrace moldings modeled in stucco, and possibly sculptured stone heads ten-

oned in conspicuous places. A number of serpent heads with tenons, and other miscellaneous stone sculptures were found.

A late occupation of the site is suggested by the finding of a stone yoke and fragments of plumbate pottery in the sloping surface debris of Structure 1.

Structure 8 differs from all others investigated in the main group. It appears to be a rubble-filled platform of two terraces facing west. The terrace walls are faced with well cut, dressed, and fitted blocks of volcanic tufa resembling that used in Copan. The platform underwent at least two building periods. The latest additions in the elevated court—a small rectangular altar attached to the front of Structure 1, and a step added between Structures 1 and 2—are constructed of these cut tufa blocks. Evidence is not sufficient at present to determine whether Structure 3 antedates the use of adobe construction and the late additions represent stone-robbing from Structure 8, or whether the use of cut stone is a late architectural feature postdating the adobe period.

The excavations have yielded rich sherd material from each architectural accretion, thus integrating more closely the domestic and civic arts of these people. Mr. Boggs remained in Salvador during the off season to devote his time to the study of the ceramic collection.

In pursuance of Mr. Dimick's program of archaeological studies in Salvador, half the force of laborers were employed in work of conservation. Terraces, walls, and floors were coated with cement to prevent erosion by the torrential summer rains. In some instances reconstruction was required to prevent badly cracked walls from falling. Shelters and drains were built where necessary.

Architecturally, Campana San Andres seems to share more general characteristics with Copan than with other well known

sites. Both are located on level valley floors, their main groups centrally placed near a permanent stream. The orientation and assemblage of the principal ruins are similar, each having a great plaza surrounded on three sides by structures and on the south by a raised, acropolis-like unit supporting massive, pyramidal temple structures. Certain terrace forms, balustraded stairways, well cut block masonry in Structure 8, tenoned stone heads, and sculptured stone incensarios are a few details these sites have in common. It would seem that Campana San Andres flourished during the Great, or Acropolis, Period in Copan. Also some connection with Kaminaljuyu may be implied by the finding of mold-made adobes in a tomb at that site. Mr. Boggs' pottery studies and future excavations in Campana San Andres undoubtedly will show a more widespread connection and a closer association with the sites mentioned.

NICARAGUA

F. B. RICHARDSON

As was stated in the introduction to this report, Mr. Richardson, who went to Nicaragua to study relatively recent stone sculpture, was diverted from that end by the necessity of investigating a series of ancient human footprints found in deeply buried volcanic deposits near Managua.

A similar discovery had been made in the seventies by Earl Flint, who was working for the Peabody Museum of Harvard University. Flint's attribution of great age to the footprints was received with considerable skepticism, no attempt was made to follow up the discovery, and the whole occurrence was soon practically forgotten. Mr. Richardson, however, who had read Flint's reports and his correspondence filed at the Peabody Museum, felt that the matter should be investigated further. On

arrival at Managua, he accordingly made inquiries and learned that footprints were still from time to time encountered in quarrying operations at El Cauce, a short distance west of the city. He at once visited the site, where by great good fortune the workmen were just bringing some of the tracks to light.

Extensive excavations, carried out with the cordial support of President Somoza, revealed most interesting conditions, best summarized by quoting the preliminary report of Dr. Howel Williams, of the University of California, who, on being appealed to by the Division, generously sacrificed his Easter vacation to fly to Nicaragua and examine the deposits.

Before the footprints were made, there had probably been millions of years of volcanic activity, as they are underlain by hundreds of feet of ash. It may be, however, that about the time the prints were formed the craters a short distance south of Managua burst into unusually violent eruption. I hope that microscopic study of the deposits will throw light on this point.

Just before the prints were produced, volcanic "mud flows" (technically known as lahars) swept across the plains around Managua and emptied into the lake. It may be that these were formed by temporary damming of the rivers that drain from the highlands to the south, at a time when the cones and craters of Asosoca, Nejapa, Tiscapa, etc. were particularly active. Whatever the cause of the lahars—and other possible causes are easy to imagine—they inundated a wide area. Soon after they came to rest, the prints were impressed. I say "soon" because the deposits left by lahars tend to harden rapidly. Somewhat similar deposits were laid down on the slopes of Lassen Peak in California in 1915 and within a few hours it was difficult to stamp an impression on them with the feet. Lahars which sweep down from the volcanoes of Java are known to behave in the same way. Incidentally, the laharic deposits of

Managua are remarkably like those which buried Herculaneum in A.D. 79.

Shortly after the making of the prints—possibly even while they were being made—they were covered by a thin veneer of black cinders. Then followed another lahar, another eruption of black cinders, and then a rapid succession of thick lahars. These last are now represented by the thick stratum quarried and used as a building stone in Managua.

An interval of quiescence ensued. In the region of El Cauce, rivers excavated a channel some 20 m. wide and at least 3 m. deep. They cut not only through the layers of volcanic mud but far into the underlying ashes. Slowly the channel was filled with sand and gravel. Subsequently, a distant volcano, perhaps in the vicinity of Masaya, erupted showers of white pumice. About El Cauce the pumice accumulated to a depth of approximately 50 cm. Once more quiet followed. Rivers cut new channels through the pumice; elsewhere a soil up to 1 m. thick was developed. Renewed eruptions covered the soil with ash; another soil, up to 30 cm. thick, was formed; more ash fell, and finally the topmost layer of soil on the present surface was laid down to a depth of 1.25 to 1.50 m. The record of events since the prints were impressed is thus a long one, as four layers of soil were formed and a deep river channel was cut.

The tracks were made by a number of barefooted adults. All those uncovered by Mr. Richardson were going in the direction of a point which at present protrudes into the lake some 500 m. to the northwest (others, however, are reported by quarrymen to be differently oriented). First to pass over the area examined were four or five individuals, who sank ankle-deep into the then fresh and very soft mud. Somewhat later others passed. The deposit had by that time become much firmer, but its surface was still sufficiently plastic to receive absolutely perfect impressions. These indicated that the people

had been walking rather than running; the steps are so short as to suggest that they may have been carrying heavy burdens.

One is, of course, tempted to infer that the makers of these tracks were fleeing from an eruption. Tracks of deer, otter, a large bird, and a lizard made at approximately the same time, and on what must then have been a bare open plain, hint at a disregard of danger that might be taken as evidence of panic. Since, however, only a few square meters of this intriguing record have so far been exposed, it is unsafe to speculate too freely.

The problem of greatest importance is, of course, that of the age of the footprints. That they are of respectable antiquity is beyond doubt, but in the absence of contemporary artifacts we have no archaeological evidence bearing on this point. In the surface humus laid down after all volcanic activity had ceased there are, however, many potsherds, and some of these appear to represent a relatively early culture. If so, and if one allows time for deposition of the intercalated humus strata and the cutting of the now buried stream bed through the thick layers of hard rock overlying the footprints, the latter may indeed be extremely old.

During the coming season the trail will be followed as much farther as means will permit. Although it is perhaps too much to hope that remains of people themselves will come to light, it is possible that artifacts may be found, and probable that further evidence will be obtained as to conditions obtaining at the time the footprints were made. Careful search will also be made in the humus immediately below, for that of course represents the surface on which the people must have lived prior to the outpourings of mud. The alluvial material in the stream bed will be examined, as well as the beds of humus laid

down during periods of quiescence. Stratigraphic studies will be carried on in the latest humus. Relatively large amounts of this can be sectioned, as its excavation will not entail quarrying off the great overburden that masks the deeper deposits. Finally, every attempt should be made to ascertain the approximate age of the flows by volcanological research and the use of such chemical and spectroscopic techniques as can be brought to bear on the problem.

It is to be hoped that the site of these remarkably interesting and possibly very important evidences of prehistoric man may be acquired by the Government of Nicaragua, and the footprints exposed this year and next be preserved *in situ* as a national monument.

President Somoza has already aided the work of conservation by the building of a diversion dam and the opening of a large drainage ditch which will turn flood waters away from present and future excavations.

CERAMIC TECHNOLOGY

ANNA O. SHEPARD

Ceramic technological investigations for the current year have included a statistical digest and final check of data on Rio Grande glaze-paint pottery, a study of plumbate ware from highland sites in Guatemala, petrographic analysis of fragments of tomb vessels from Kaminaljuyu, Guatemala, and temper identification of the collection of Yucatecan sherds in Merida.

The study of glaze-paint ware was undertaken mainly to clarify and illustrate the place of technological analysis in ceramic archaeological research. Pueblo rather than Maya pottery was chosen as the basis for a critical evaluation of the results of such analysis because the frame-

work of Pueblo archaeology is better known than is that of the Maya. In particular the distribution of pottery types and their time relations have been traced in considerable detail in the Southwest. Also important to the study was the fact that information on geological formations and natural occurrences of ceramic materials is more easily obtained for the Southwest than for Central America. As long as archaeological research is in the stage of reconnaissance, in which the mapping of distributions forms a major activity, there is a tendency to limit laboratory analysis of pottery to routine identification. Not until there have accumulated the basic data from which specific problems regarding cultural development and relationships can be outlined, is it possible to utilize fully and effectively the facilities for exact identification which ceramic technology offers. The statistical summary of the technological data on glaze-paint ware shows how composition of paste and paint provide specific evidence regarding the area in which the ware was made, the principal centers of its production, and the extent to which it was traded. These are questions which hitherto have been only subjects for speculation. Likewise the study has shown the importance of correlating stylistic and technological evidence, particularly in instances where there has been mixture of local varieties of pottery through trade. The manuscript, which is now completed, was written in the hope that a striking illustration of the importance of proper sampling, specific and exact identifications, and complete correlation of technological and stylistic data would enable the archaeologist better to judge the type of problem for which technological analysis can effectively be employed, and prevent the waste of time often involved in making meaningless analyses.

The petrographic analysis of plumbate ware has been continued in order to accumulate evidence bearing on the place of manufacture of this type of pottery, which is of outstanding archaeological importance because of its wide distribution in Middle America. Theories which have previously been advanced regarding its origin have been based principally on the geographic distribution of the ware, and on its stylistic affinities. Information regarding distribution has been gained in considerable part from local collections and is therefore not only incomplete but also possibly misleading. In consequence both Salvador and the highlands of Guatemala have been seriously proposed as the source of the ware, and in each case the arguments are based on supposed frequency of occurrence. Mexican traits are noticeable in vessel shapes, in Tlaloc effigies, and in motives of incised design. These features, however, give us no means of ascertaining how far into Central America the Mexican influence may have penetrated. The composition of the paste of the ware offers more specific information. For many years the hope has been harbored that the particular kind of clay from which plumbate ware was made might be found. A direct search for the clay would be impracticable, and the chances of obtaining ethnological leads from the survival of tradition regarding the ware are practically negligible. The evidence of composition, which at present seems most promising, is of quite a different nature. Plumbate ware contains very fine tempering material which consists of mineral grains and glassy rock fragments. All plumbate sherds which have been analyzed (including specimens from Salvador; from San Agustin Acasaguastlan, Zacualpa, Tajumulco, and El Quiche, in Guatemala; and from Chichen Itza in Yucatan) contain this same kind of

temper. If identical temper should be found in the common wares indigenous to a site where plumbate ware was abundant, we should have circumstantial evidence regarding the place of manufacture of plumbate. Pottery from Tajumulco, a site in the northwest highlands, excavated under the auspices of the Museum of New Mexico, has been studied in detail because of the considerable number of sherds in the collection having the appearance of unsuccessfully fired plumbates. The petrographic analysis of sherds from this site revealed, for the first time, temper similar to that of plumbate in sherds of nonplumbate style. It would be premature to conclude from this occurrence that Tajumulco was a place of manufacture of plumbate ware, because only a relatively small number of sherds were brought out from the site and made available for study. It is, therefore, possible that the plumbate sherds and also the few nonplumbate sherds with similar temper are intrusive in the site. Nevertheless a very promising means of locating the place of manufacture of plumbate ware has been recognized.

The surface finish of plumbate ware is no less distinctive than its shape and decoration, for it is unique in American Indian pottery. The peculiar range of colors and glazelike luster have long attracted and puzzled the archaeologist; microscopic examination and chemical analysis reveal properties which, though less obvious, are no less unusual and interesting. The work completed to date has conclusively disproved a fallacy which has long persisted in the literature, the supposition that the material was a lead glaze. Analysis has shown that the lustrous material is basically a claylike substance which was applied as a slip. This disproves a second fallacy, the supposition that the surface and body were both the same, or that the surface layer was produced as an exudation

of material from the body. Studies are being continued on the crystalline structure of the surface coat, its firing properties, the cause of its luster, and the technique of application.

During the fall, a month was spent in Mexico, two weeks being devoted to identification, with the binocular microscope, of temper in the collection of Yucatecan sherds at Merida. The primary object of the study was to aid in the classification and description of the pottery undertaken by Dr. Brainerd. The variety of materials found and their distribution, however, also indicated that paste composition will, here as elsewhere, give evidence of sources of types and the extent of trade in them, when adequate samples are made available for study.

A series of sixty-five fragments from Kaminaljuyu tomb vessels was analyzed petrographically for purposes of record and evidence of source. Since the great majority of pastes contained material of volcanic origin, either vitric or crystal tuff, it was necessary to make a detailed study of all features which might distinguish tuff from different localities. Particular attention was given to the structure of the tuff and the heavy minerals. As a result of the analysis a few vessels were clearly indicated as intrusive, but the temper of the majority was of the type common in the Guatemala highlands.

A small collection of sherds of cylindrical tripod vessels from Teotihuacan, loaned by the American Museum of Natural History through the courtesy of Dr. Vaillant, were sectioned and the paste compared with that of cylindrical tripods from Kaminaljuyu. Although the tempers in both sites are of volcanic origin, they are readily distinguished in thin section. On the other hand, identity of paste of thin orange ware from the two sites proved that

the vessels represented were all from the same source.

During the summer of 1940 courses in theoretical and applied spectroscopy and colloid chemistry were taken at Massachusetts Institute of Technology. Emission spectroscopy offers the most practicable method for complete qualitative analysis of small samples, and the only method for determining trace elements in such samples. It is therefore a valuable means for analysis of paints and slips. The course in colloid chemistry covered fundamentals which contribute to an understanding of the properties of clay and also of many characteristics of primitive pottery.

SOUTHWESTERN ARCHAEOLOGY

E. H. MORRIS

Investigation of early Anasazi remains near Durango, Colorado, described in the two preceding Year Books, was continued by Mr. E. H. Morris from the middle of May until August 6, 1940. The site opened was about 12 km. north of Durango on a steep timbered hillside overlooking the Animas valley from the west. Evidence of man's activity at the spot consisted in a vaguely defined terrace which did not conform to the natural contour of the slope, with a skirt of refuse-stained earth on the downhill side, on which were many chips of implement stone but no potsherds. The resulting inference that this site in the open had been occupied during the pre-pottery horizon represented by the cave some 3 km. distant which was explored in 1938 was borne out by excavation.

The terrace proved to be some 40 m. long and 18 m. wide, with a maximum depth of 3 m. The mass of it was composed of earth moved during leveling operations, the wreckage of dwellings, and refuse that had accumulated during their

occupation, augmented by stones and earth washed down from the slope above. The single-roomed dwellings had lain close together along the hill face in two rows, one 2 to 3 m. above the other.

Constructional practice was as follows: First, the hillside was dug into and the earth piled out in front until a level spot of the desired size had been provided. Upon this a wood-and-mud house was erected. Such dwellings were short-lived, the great majority of them having been destroyed by fire. If the site was to be built upon again, the residue of conflagration was scooped down the hillside onto the ever growing refuse talus; excavation was carried a little farther into the slope at a slightly higher level than before; the fresh earth was spread over the old floor, and a new dwelling was erected upon the surface thus provided.

Presumably because it was encroaching on the front of the upper level, the lower row of chambers was abandoned after only a few renewals and subsequently became deeply buried under debris and refuse cast downhill from the upper. The latter continued to be built upon until, in at least one place, seven floors lay one above another like a stack of offset pancakes leaning against the hill.

Although the houses varied somewhat in outline, customarily they were roughly circular and ranged from 3 to 10 m. in diameter. Each floor was saucer-shaped, with a heating pit at the center. A good deal of the area was taken up by storage bins, which usually consisted of a subfloor part lined with stone slabs, surmounted by an open-topped mud dome 1 m. or more in height. Less frequent storage devices were mud domes without the under-floor part, and relatively huge jug-shaped pits with mouths at floor level. Metates were a normal accompaniment of the storage bins, from two to six being set at convenient

points about the room, bedded in mud or propped up on stones.

Discovery of the manner of construction of the house shell proved baffling in the extreme. Vain search was made for butts of heavy posts to support the roof and for the stubs of inclined peripheral timbers such as are always to be found in the dwellings of the first pottery-making people, of somewhat later date. Finally, from vestiges observed here and there, it became evident that the walls had consisted of wood-and-mud masonry—logs, poles, twigs, and chunks of all sorts laid horizontally, the interstices filled with mud, and the surfaces chinked, log-cabin fashion. Those roofs of which traces remained had been cribbed with horizontal timbers gradually indrawn, so that the finished house must have resembled an inverted bowl with a break in curve at the junction of wall and roof. The placement and character of the entrances could not be ascertained.

Artifacts from the site consisted of metates grading from basin to trough shape, with irregularly bounded grinding surfaces; hand hammers and choppers; a wide variety of knife blades and projectile points; a profusion of bone implements, the most distinctive types of which are notched animal ribs and scapulae of unknown function; and a limited number of beads and ornaments. Perishables were represented by a few charred shreds of coiled basketry and cloth, carbonized corn, and some impressions of matting in clay. The dead were deposited with little care in rude pits gouged into the natural hillside, or into refuse earth or house debris as convenience dictated, with an occasional interment in an abandoned cist. The people were of short stature, with skull form ranging from meso- to brachycephalic.

The 1940 site in the open paralleled in every respect the nearby cave excavated in

1938. The culture that flourished in these places was classic Basket Maker or Basket Maker II of the Pecos nomenclature. That culture was agricultural (corn-growing), pre-pottery, and characterized by the absence of hafted mauls and axes as well as by the use of spear thrower and dart instead of bow and arrow. It differs from the accepted picture of Basket Maker II in that the people were comparatively short-skulled and constructed for themselves dwellings that were both commodious and substantial. A satisfactory quantity of charred timbers was recovered. When finally these have been dated, it is

to be expected that the hillside site will prove to have been inhabited not far one way or the other from A.D. 300.

The fall and winter of 1940 and the early months of 1941 were spent by Mr. Morris mostly in desk work and the study of specimens. During that interval, in collaboration with Robert F. Burgh, there was brought to completion a report on Anasazi basketry, which was forwarded to the editor in June. Preparation of a report on the Durango sites which will add materially to the knowledge of Basket Maker culture is now in progress and will go to press early in 1942.

SOCIAL ANTHROPOLOGY AND LINGUISTICS

R. REDFIELD, S. TAX, A. VILLA

Beginning in October 1940, Dr. Tax spent eight months and Dr. Redfield five months in Guatemala, resuming field work among peoples of the midwest highlands. In previous seasons Dr. Redfield had studied the mode of living of the Ladinos of the village of Agua Escondida, on the eastern side of Lake Atitlan. This year he devoted his attention to the San Antonio Indians, whose pueblo is the most important settlement in the municipio wherein Agua Escondida is but a recent hamlet of invading Ladinos. The materials obtained from the San Antoñeros have two principal uses for the Institution's ethnological project. Combined with the data obtained from the Ladinos, they will make possible a monograph on the entire municipio community, which includes within it the three principal kinds of people living in the midwest highlands: Indians native to the municipio, invading Ladinos, and Indians who have moved into the municipio from other communities. It is proposed to describe the life of the municipio in terms of its bi-ethnic,

or multi-ethnic, population, using ethnic differences, resemblances, and relationships as a general theme in terms of which to examine customs and institutions. It is expected that understanding will thus be increased of some of the basic features of midwest highland life: its commercialism, its secularism, and its general dependence on formal regulation and control. To this end Dr. Redfield visited almost every part of the municipio, and mapped the residences and lines of communication in the most rural corners of the community as well as in the pueblo and hamlets themselves.

In the second place, the work with San Antonio Indians closed one link in a developing chain of comparisons. Previously we had knowledge of the customs of several Indian communities situated along the lake, of the Ladinos of Agua Escondida, and of the Indians of Chichicastenango to the north. But we did not know which elements of culture were to be attributed to Ladinos *per se* and which to local differences among Indians, differences which

Latinos might to some extent share. Now that we have knowledge of the Indians and Latinos of the same municipio, distinction may be made with some confidence between local and ethnic culture variations, and at the same time one may begin to see where are to be found the frontiers of diffusion and culture change, between Indian and Indian, and between Indian and Latino.

Dr. Tax returned for his third field season at the village of Panajachel, with two main objectives: to obtain data needed to complete his monograph on the economics of the Indian community, and to determine the degree to which material on the mental life of individual Indians is representative of that of the whole community. For the second purpose, a sample of over four hundred items of belief was tested on at least three, usually four or five, and sometimes more, selected Indians. Conclusions in this study, which will form the substance of a second monograph, are still to be worked out. In addition, some quite new information was obtained, and considerable work was done with informants never previously engaged. Noteworthy is a life history obtained from a middle-aged Indian with whom Dr. Tax was especially intimate.

Dr. Tax also devoted some time, with Sr. Juan Rosales, to the preparation of their report on the town of San Pedro, where Rosales did the field work. This report, of which some two hundred typed pages are now ready, is being written in Spanish. Rosales spent most of the year in Solola, writing the monograph, but he continued to collect material until the end of 1940. Since then, his chief contact with San Pedro has been through Sr. Agustin Pop, the Indian interpreter who has been writing a diary and collecting courthouse records for Rosales. In order to finish the report on San Pedro, which requires their

constant collaboration, and to obtain training that will add to his value, Rosales accompanied Tax to Chicago at the end of May for a stay of about a year, aided by funds of the Rockefeller Foundation.

Early in January was inaugurated the experiment in ethnographic method conducted by Mr. Benjamin Paul (Social Science Research Council Fellow) under the direction of Redfield and Tax. Mr. Paul is in San Pedro engaged in an independent study of the community for comparison with that of Rosales. Since Rosales kept a record of origins of his data, and Paul is doing the same, a comparison of information and conclusions may well yield very significant information for the study of field techniques.

Besides the work on selected communities, advances were achieved this year in extending and systematizing the more comprehensive study of all Indian Guatemala into which the community studies fit as special parts. Taking advantage of several years of experience in villages and towns of western Guatemala, Tax and Redfield developed a schedule on which may be quickly recorded a great many of the basic and readily comparable facts about local communities. As the municipios are both natural culture groups and also administrative units of the Guatemalan government, it is possible to use the municipio as a unit of investigation, and to combine on a single schedule and program of survey both material taken from formal government records and information obtained orally from informants. In order to make the best use of the former class of material, Redfield and Tax first spent some time in Guatemala City and in offices of municipal government in order to understand the machinery of that government and the records in which its doings are set down. The resulting schedule passed through several stages of revision,

and was tried out in municipios in the area where the principal field work has been done. It is now ready for general systematic use in a survey of this part of Guatemala, or, indeed, for surveys in other parts of the country.

As one means of extending the general background of knowledge of Guatemala, and with the incidental objective of giving the schedule a further trial, Tax and Redfield made a five-day trip of reconnaissance into eastern Guatemala. The itinerary included communities in the territory of the Pokoman and of the Chorti, and extended to Esquipulas, near the Honduran border. The trip resulted in a number of achievements. The worth of the schedule was demonstrated in San Pedro Pinula, where reliable and detailed information was obtained from municipal authorities in complete response to the schedule in less than two hours. Later in the afternoon and evening an excellent sampling of ethnographic data was obtained from an Indian family of the town. A very creditable paper on this municipio could be written from this single day of work. In the second place, confirmation was given to a hypothesis carried into the field (from a reading of Wisdom's report on the Chorti) that Chorti culture is more like that of Yucatan than it is like that of the western highlands of Guatemala. Furthermore, what was learned on this trip gave weight to the suggestion that the Indian societies of eastern Guatemala are more sacred and personal, and less formally institutionalized, than are those of the midwest highlands with which the project began. And, finally, there was discovered, or rediscovered, an excellent series of adjacent communities, between Guatemala City and the Pokoman villages, within which to study the progressive ladinoization, or de-Indianization, which is generally taking place in Guatemala.

In 1940 Dr. J. S. Lincoln received from the Carnegie Corporation a grant for ethnological studies among the Indians of the Nebaj region in the Department of El Quiche, Guatemala, a group which has had relatively little contact with European culture. Dr. Lincoln's work, carried on under the auspices of the Division of Historical Research, proved so interesting that a small further grant was made by the Division for its continuance in 1941. Dr. Lincoln was engaged on this research when he was taken seriously ill. He was brought with great difficulty over the mountains from Nebaj to Sacapulas by Indian porters and by motor to Guatemala City, where he died on May 2, 1941.

Dr. Lincoln had completed an extremely thorough study of the calendar system now in use by the Indians of Nebaj, showing it to retain many important elements of the ancient Maya method of reckoning time. A manuscript embodying his findings was received shortly before his death and will be made ready for the press. Dr. Lincoln's voluminous notes on social, religious, and political organization and material culture are being studied by Mrs. Lincoln with a view to their ultimate publication.

The untimely death of Dr. Andrade has, of course, halted field investigation of the Maya languages. As stated in the introduction to this report, however, Mr. Bradshaw has been engaged to put in final shape for publication Dr. Andrade's almost completed monograph on Yucatec, a work in which are exemplified his remarkable abilities as a logician and as an analyst of primitive tongues. Attempt is also being made to arrange for the continuation of the research. That it should go on is most essential, not only for the light which it can shed on problems of Maya history, but also in order that the vast body of materials so meticulously recorded

by Dr. Andrade may be augmented and synthesized as a contribution to linguistic science in general. The first step must, of course, be a thorough study of those materials, in order to determine how they may best be utilized and to ascertain what

additional field work will be necessary. This stock-taking has been entrusted to Dr. Abraham Halpern, of the University of Chicago. On receipt of his report, in about a year's time, it will be possible to give consideration to plans for the future.

POST-COLUMBIAN HISTORY

HISTORY OF THE MAYA AREA

F. V. SCHOLES

Continued study of the documentary sources for the colonial history of Yucatan constituted the major activities of Mr. Scholes and Miss Adams during the past year. Most of these documents consist of series from Spanish and Mexican archives, of which photographs or typewritten copies had been made in former years. It may be recorded, however, that despite unsettled conditions in Europe, film copies of extensive series in the Archivo General de Indias in Seville have been received during recent months.

Most of the source materials studied during the year consisted of lawsuits, administrative reports, private petitions, and official correspondence which illustrate the following problems: (1) the preconquest political geography of Yucatan; (2) the government of Indian pueblos subsequent to the conquest; (3) the early history of the encomienda in the Peninsula; and (4) the schedules of tribute payments. Notes and extracts based on the sources, together with similar data previously accumulated, have been carefully classified pueblo by pueblo, and this elaborate note file is producing dividends in the form of clues or answers to many hitherto unsolved questions in the early history of Yucatan.

For example, the tribute roll of 1549, the most important source of information for the beginnings of the encomienda in Yucatan, lists many pueblos which have been

difficult to identify and locate. The accumulated pueblo-by-pueblo data have made possible positive identification of most of the doubtful entries. In the same way several questions concerning the pre-conquest cacicazgos and their respective boundaries have been solved. Finally, the documents are yielding more and more information concerning the details of pueblo government and the functions of pueblo officials subsequent to the conquest.

These problems have great importance for the studies of Mr. Roys and Dr. Chamberlain, as well as for the investigations of Mr. Scholes and Miss Adams. In the summer of 1940, Mr. Roys came to Washington for a series of conferences with his colleagues, during which the documentary evidence relating to questions of common interest was thoroughly reviewed. These conferences proved extremely valuable, and satisfactory answers were worked out for many moot points. It was clear, however, that first-hand information, obtainable only in the field, will be required to supplement the documentary data on several questions relating to preconquest political geography, or to make possible more accurate interpretation of such data. For this reason Mr. Roys and Mr. Scholes plan to spend a few weeks in Yucatan during the winter of 1941-1942, in order to visit certain key areas, especially in the eastern part of the Peninsula.

During the past year, Mr. Scholes has also completed a series of articles on the history of New Mexico in the seventeenth

century, which have been published serially in the *New Mexico Historical Review*. These articles are based on source material obtained from foreign archives prior to the time he joined the staff of the Division. During 1941-1942 Mr. Scholes will serve as visiting lecturer at the University of New Mexico. The program of research on the history of Yucatan will be carried on as usual, however, except that headquarters for the year will be established in the Southwest instead of in Washington.

Dr. Chamberlain has devoted most of the year to further revision of his manuscript on Montejo and the Spanish conquest of Yucatan, preparatory to publication of this important study, which will be the first in a series of volumes on the colonial history of the province. Mr. Roys has also actively collaborated with Dr. Chamberlain by preparing materials for a survey of Maya institutions and culture on the eve of the conquest, to be incorporated in Dr. Chamberlain's volume.

In Mexico City, Sr. Rubio Mañé has continued his survey of a section of the National Archives known as the "Papeles de Bienes Nacionales." The great volume of documents in this series, which consists of ecclesiastical archives, has made the survey a longer task than was expected, but when the work is completed, Carnegie Institution will have made a valuable contribution to the work being carried on by the archive, which contains the greatest collection of colonial materials in North America.

UNITED STATES HISTORY

LEO F. STOCK

Volume V of Dr. Stock's *Proceedings and debates of the British Parliaments respecting North America* (to 1783), now in press, will be ready for distribution in early autumn. The period covered by

this volume (1739-1754) was one of continuous war and its ensuing problems. After the peace of Aix-la-Chapelle in 1748, charges of bad faith, particularly against France, brought further dissensions, and in the year with which the volume closes the French and Indian War began. The records for these years are naturally filled with accounts of the British Parliament's consideration of the issues arising from the war. Much of the criticism of its conduct was rooted in party conflict, which resulted in the retirement of Walpole as head of the government. In these debates and proceedings students will find some interesting parallels to present-day problems and policies.

In addition to the consideration of these issues and of the recurring need felt for the control of colonial trade and manufacture, in the examination of which enlightening details are presented, the Parliament of Great Britain concerned itself with such matters as land tenure and slavery in Georgia, the establishment of the new colony of Nova Scotia, colonial bills of credit, the conduct of the Hudson's Bay Company, and the naturalization of foreign Protestants in the colonies, in the discussion of which question the "Jewish problem" arose.

The main contribution to American history made by the proceedings of the Irish Parliament for this period is the information to be found respecting the elusive topic of the transportation of "felons and vagabonds" to the American colonies. In 1743-1744 there were presented, pursuant to order, lists of all persons sent during the previous seven years from each county of Ireland. In all, 1920 names are listed; in addition are given the costs of transportation and, in some instances, the places to which the convicts were sent and the prices at which they were sold.

In the preparation of this volume the

editor has used, in text and for purposes of annotation, considerable material which he found in England during his visit in 1938. A substantial beginning has been made on the sixth volume of the series.

During the year Dr. Stock has been consulted and his materials used by several university professors and students. On April 13, 1941, he spoke before the Irish History Club of the District of Columbia on one phase of his work.

Work on the *Guide to materials for American history in the libraries and archives of Paris* was continued during 1940 and 1941 by John J. Meng under the supervision of Waldo G. Leland. Vol-

ume II, which deals exclusively with the extensive French Foreign Office archives, is now being prepared for publication by the multilith process. The manuscript of the next volume, which will include the War Office archives, is nearing completion. By far the largest segment of material in the War Office consists of the "archives anciennes." This part of the archives, covering a period of approximately two hundred years (1615-1815), has been analyzed and described by volume and folio in considerable detail. It is expected that the entire manuscript for this depository will be completed before the date of publication of volume II.

HISTORY OF SCIENCE

GEORGE SARTON

Introduction to the History of Science. At the time of submission of the last annual report, Dr. Sarton believed that the analytic part of his investigations on "Science and learning in the fourteenth century" was virtually completed, and that as soon as the Sanskrit, Chinese, and other Oriental notes were revised, the writing up of his materials would be relatively easy. He had left out of calculation a vast amount of notes, put aside for years, relating to anonymous writing or inventions, such as chemical processes, manufacture of paper, glass, clocks, powder, arms, and armor. The elaboration of those notes has required considerably more time than had been foreseen. In spite of the fact that most of Dr. Sarton's time during the year was devoted to the *Introduction*, he has finished only eight chapters out of twenty-eight. Since, however, certain methodological difficulties encountered in the writing of those chapters will have been solved by the time he has fin-

ished his work on the first half of the fourteenth century, the redaction of chapters 15 to 28 will be easier and quicker than that of chapters 1 to 14.

Other investigations. In order to speed up the *Introduction*, larger investigations of any other kind were systematically avoided. A number of smaller studies had to be carried out, however, for the sake of reviews, or for the writing of the preface to a friend's book, or because of queries sent to Dr. Sarton or suggested to him in other ways.

Dr. Pogo investigated the relation between the inscriptions of Mohenjo-Daro and those of Easter Island. He interpreted the daily and annual movements of the twenty-nine visible decanic constellations (stellar or Sky circuit) and of the seven invisible ones (solar or Netherworld circuit), on the basis of the Egyptian cosmological papyrus Carlsberg no. 1, recently published by L. O. Lange and O. Neugebauer.

Mr. I. Bernard Cohen continued his research on the rise of empirical science in the eighteenth century, especially with regard to optics and electricity. He completed the preparation of the first American edition of Franklin's "Experiments and observations on electricity made at Philadelphia," to be issued next October by the Harvard University Press. He examined the relation between Anquetil-Duperron, Franklin, and Ezra Stiles.

Editing of Isis. No. 84 of *Isis*, completing volume 31, was actually published in Belgium in October 1940, though it bears the date April 1940. This was the latest number published in Belgium. Only a few copies reached America. This is easy

to understand, because *Isis* is dedicated to the study of the history of science of every time and of every people, and also because it deals with many controversial questions, such as science versus society, science versus religion, education, etc. Publication of the remaining volumes of *Isis* (32) and *Osiris* (8, 9), already proofread, has been deferred until the war is over.

In the meantime the new American *Isis* has begun to appear (volume 33, parts 1 and 2). It is now published at the expense of the History of Science Society.

The proofreading and editorial management of *Isis* are in the hands of Dr. Pogo, who is also conducting all kinds of minor investigations entailed by the editing.

PUBLICATIONS

MARGARET W. HARRISON

During the current year two papers have been published in the Institution's formal series: *Late ceramic horizons at Benque Viejo, British Honduras*, by J. Eric S. Thompson, with notes on the classification of the painted wares by Anna O. Shepard; and *Maya arithmetic*, by Mr. Thompson. These papers are preprinted as Contributions 35 and 36 respectively from the seventh volume of "Contributions to American Anthropology and History." Contributions 37 and 38 are now in press: *Substela caches and stela foundations at Copan and Quirigua*, by Gustav Strömssvik, and *The wall of Mayapan, with notes on the ruins*, by Ralph T. Patton. This volume is being reproduced by multilith.

Nearly ready for distribution is the monograph *Maya Indians of Yucatan*, by Morris Steggerda, who has based his conclusions primarily on a study of Piste, Yucatan. After a historical introduction, Dr. Steggerda describes in detail the In-

dians' personality traits, physiological features, everyday activities, family histories, and agricultural system. A large number of graphs, tables, and photographs illustrate the book.

The manuscript of *Anasazi basketry, Basket Maker II through Pueblo III: a study based on specimens from the San Juan River country* has been completed by Earl H. Morris and Robert F. Burgh. It is expected that this monograph will be published by the end of 1941.

The Xiu family chronicles has been finished by Sylvanus G. Morley and Ralph L. Roys. The manuscript will be microfilmed in the fall of 1941 and film positives will be distributed to order.

Two new series of publications have been started by the Division under the editorship of J. Eric S. Thompson. "Notes on Middle American Archaeology and Ethnology" are designed to record in permanent and accessible form the random bits of information that come to light in

the field or in the museum. Five Notes have been issued: (1) *Clay heads from Chiapas, Mexico*, by A. V. Kidder; (2) *Pottery from Champerico, Guatemala*, by Dr. Kidder; (3) *Ruins of Culuba, northeastern Yucatan*, by E. Wyllys Andrews; (4) *The missing illustrations of the Pomar relación*, by Mr. Thompson; and (5) *An ethnological note from Cilvituk, southern Campeche*, by Mr. Andrews.

The second series, "Theoretical Approaches to Problems," is intended to afford circulation to current, tentative interpretations of data as they become available. The editor, Mr. Thompson, has written the first number in this group of papers, *Dating of certain inscriptions of non-Maya origin*.

Volume V of *Proceedings and debates of the British Parliaments respecting North America*, by Leo F. Stock, covers the period 1739-1754. It is now in press

and will be published in the fall of 1941.

Now being prepared for multolith is volume II of the *Guide to materials for American history in the libraries and archives of Paris*. The manuscript for this volume, which covers the Foreign Office Archives, has been compiled by John J. Meng under the direction of Waldo G. Leland. The volume will be ready for distribution in 1942.

Edmund C. Burnett's *The Continental Congress*, an interpretative volume based on his series *Letters of members of the Continental Congress*, is announced for publication in October 1941 by the Macmillan Company with the cooperation of the Carnegie Institution of Washington.

On the basis of similar cooperative arrangement with the University of Chicago Press, Robert Redfield's *The folk culture of Yucatan* will be published in July 1941.

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SPECIAL PROJECTS: HISTORICAL RESEARCH

MARION E. BLAKE, Bradford, Vermont. *Preparation of a monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman.* (For previous reports see Year Books Nos. 38 and 39.)

The first part of the monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman is progressing as rapidly as is possible under the circumstances. Three chapters—"Materials," "Cyclopean, polygonal, and quasi-quadrangular masonry," and "Arches and vaults in cut-stone masonry"—have been submitted to the Carnegie Institution in as nearly finished condition as is feasible at the present time. The preliminary work is done for the chapter on concrete vaults. Thus the entire field with the exception of kiln-

baked bricks has been covered after a fashion, so that there should be no more surprises. Work is again progressing rapidly.

In the second half of the monograph, which Dr. Van Deman has written in part, it is hoped to cover the ground by presenting the facts in historic sequence; that is to say, giving an epitome of every form of construction for each period with especial emphasis on the facts which have chronological significance. The monograph, if completed, should prove to be the fundamental work on Roman construction for many years to come.

E. A. LOWE, The Institute for Advanced Study, Princeton, New Jersey. *Collection and study of paleographical material.* (For previous reports see Year Books Nos. 9 to 35 and 37 to 39.)

With the libraries of Italy inaccessible, it has been impossible to complete volume IV of the *Codices latini antiquiores*, owing to a lack of complete data on some items. All efforts to gain the necessary information by correspondence have failed. Thus, if the volume is to see the light next year, the difficulty will have to be obviated by ignoring the gap; unless, indeed, the Clarendon Press is prevented from printing the volume because of pressure of work for the government. As field work abroad was out of the question, most of the year

was spent in Princeton with only occasional visits to other libraries. Plans have been drawn up for a study of the script called *capitalis rustica*, and a good bibliographical foundation has been laid. A systematic survey has been begun of the material furnished by papyri. The next step will be to examine the original papyri preserved in this country, and then to collect photographs of those preserved abroad. As most of these have been published in facsimile, considerable headway could be made despite present world conditions.

PALEONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. (For previous reports see Year Books Nos. 20 to 39.)

In the report on President Emeritus research transmitted in 1939 (Year Book No. 38), a program of investigation was outlined which included those pieces of research that were conducted personally, those which were carried on in cooperation with associated investigators, and those which represented the development of what seemed to be major philosophical or human questions naturally arising from the researches which had been undertaken. In 1940 (Year Book No. 39) the subject of organization of research was reviewed, and the special reports were presented under the names of those who had conducted the research.

This report involves the principles expressed in both of the earlier years, but emphasis is placed on results from groups of investigations on certain major problems in which cooperation of the investigators has been an element of primary importance.

CORRELATED INVESTIGATIONS IN THE JOHN DAY REGION OF OREGON

Among projects which have occupied attention of the writer over many years, and have brought cooperation of numerous able students, one of the most important concerns the various phases of paleontological and geological research carried on in the John Day region of eastern Oregon. This region is now known to be one of the exceptional sections of the world in its presentation of clear interlocking records of geological history, volcanological activity, connected stages of physiographic sequences, and paleontological successions representing large groups of higher ani-

mals, marine invertebrates with wide relationships, and numerous types of higher plants. Certain of its features, such as the stupendous series of lava flows known as the Columbia Lava, are among the spectacular geological phenomena of the world. Others, as some of the great series of sediments composed in large part of volcanic ash, and the long evolutionary series of higher animals, though not unique, are outstanding.

Work on the John Day area begun by the writer at University of California in 1899 has been carried on almost continuously up to the present time through the University and the Carnegie Institution of Washington.

The first impetus to research in this important region was given by the hope of securing adequate original material to use in realistic illustration of the history of life. It was known that in the John Day area a series of unusually clearly exposed geological formations contained well preserved fossil remains demonstrating the evolution of the horse, the camel, and other important types of life illustrating stages of evolutionary development. Our expedition into Oregon was successful in its first objective, namely, the securing of material of high educational value. To our surprise, it was discovered also that although the region was widely known, the geology and paleontology had received relatively little intensive study, and offered a remarkable opportunity for research.

The exceptional research values of the John Day area are due partly to the fact that this geological section and paleontological sequence cover an unusually long period with but few major interruptions,

and partly to unusual preservation of the materials presenting the story. This preservation is due in considerable part to the fact that this area was covered for many millions of years by the tremendous series of lava flows known as the Columbia Lava. Had these sheets of molten rock not been poured over the region ages ago, much of the original record would doubtless have been removed by erosion, or destroyed by other geological processes. Exposure of the John Day section, affording opportunity for present-day studies, was brought about by carving out of the existing valley by the John Day River.

As years passed, the various problems on which research was undertaken became in a measure the individual responsibilities of a considerable number of men. Since the elements of the several studies were intimately related, it was important that these investigators keep close touch with one another, and thus there grew up an informal organization in which each individual project was carried forward in a measure through the aid of others concerned with related problems.

The types of investigation represented in the John Day project divide themselves naturally into four groups. Of these, the studies in geological history, conducted largely by Dr. J. P. Buwalda and assistants, furnished the basis of all researches, since they provided the geological book out of which the story of life and of other events is read. A second group of investigations, carried out by Dr. Chester Stock, Mr. E. L. Furlong, and associates, comprises all the data obtained from the historical or evolutionary record of the higher or vertebrate animals, which have illustrated the processes of evolution in so spectacular a way. A third group includes the studies by Dr. E. L. Packard and associates on history of the numerous types of animals of lower orders, obtained principally

from marine deposits in the older formations of the region. The fourth program of research, carried out under supervision of Dr. R. W. Chaney, concerns the history of plant life, as represented through vast numbers of remains beautifully preserved in many of the formations.

Geological work of John P. Buwalda. Researches of Dr. Buwalda on the geological record of the John Day area have been carried on intensively over a period of about twenty years with the aid of student assistants and of associated investigators. The areas selected have been so located as to give practically the whole of the geological and paleontological story and to present the data in the clearest possible way. The results of this work constitute a record of exceptional importance in the geological history of western North America, and furnish the basis for both academic and economic studies.

Dr. Buwalda describes the plan and results of his studies as follows:

"In the John Day region of north-central Oregon two areas have been mapped in great detail and their structure and geologic history deciphered very fully. One of the districts is the Mitchell Quadrangle, with an area of about 900 square miles; it lies in the drainage basin of the John Day River, north of the Ochoco Range, and contains the town of Mitchell. The second district is the Picture Gorge Quadrangle, much smaller in area, and lying immediately to the east of the Mitchell sheet. The geological conditions in the two quadrangles are rather similar and the results of each study supplement those of the other.

"On the detailed field maps the areal distribution of the different formations was recorded and their attitudes with reference to a horizontal plane were measured and set down at hundreds of points. These data furnish the basis for the con-

struction of cross sections, which show that the areas have been moderately folded and somewhat but not extensively faulted, and that the successive formations are usually unconformable upon those preceding them. Some of the formations are marine sediments and others are land-laid deposits, and granite, very ancient metamorphic strata, and lavas form other units in the series. The formations differ in age by millions of years, and sometimes the older of two formations was sharply deformed and greatly altered or even swept away in large part by erosion before the next formation was deposited.

"The structure and geological history of the Mitchell and Picture Gorge quadrangles are now well understood, and from this knowledge a general comprehension of much of central Oregon is gained, for surrounding areas of thousands of square miles in extent have similar structure and have experienced a quite similar history. A summary of the geological history of this region has been published as 'Earth history of a portion of the Pacific Northwest' in *Cooperation in research* (Carnegie Institution of Washington Publication 501, pp. 695-710, 1938).

"An extensive description of the geology, with geologic maps and cross sections, is being prepared for publication. The precise field data, made possible largely by the availability of excellent topographic maps in recent years, corroborate very fully the geological results published by Dr. Merriam in a classic paper more than forty years ago, and permit extension of the earlier conclusions, also affording much additional quantitative information."

Studies of Chester Stock and E. L. Furlong on faunal zones of vertebrates. The work of Dr. Chester Stock and Mr. E. L. Furlong, with associated students and investigators, has brought out in recent years with increasing emphasis the fact of faunal changes in the formations of the John Day

region, corresponding in general to the succession of geological or stratigraphic units or levels in the series of deposits. The problem of faunal changes has been examined with reference both to evolution of individual types and to variation of life assemblages described as faunas. Where these horizons are carefully defined, the information made available is usually sufficient to permit determining the age of any particular formation through knowledge of the organic remains entombed in the deposits.

Some of the results of work on this problem are presented in the following quotations from Dr. Stock's report:

"In the past year emphasis has been placed on interpretation of evolution as exemplified by individual groups of mammals whose remains are found in the John Day, Mascall, and Rattlesnake formations of the type section in this region. These studies give a clearer picture of the course of evolution among the horses, carnivores, and oreodonts during Middle Tertiary time than is possible elsewhere in western North America. The abundance and variety of the fossil remains, the fine state of preservation of much of this material, and the ease with which their position in the stratigraphic sequence can be determined make these fossil assemblages of paramount importance in tracing the history of life in this classic area.

"Recognizing the type section of the John Day region in and about Picture Gorge as a standard, attempt has been made to learn whether deposits representing some of the formations in adjacent areas may show features in the sediments or in the faunas which supplement the information obtained in the type section. Much field work has been conducted during the past year to this end. Thus, tuffaceous deposits exposed in the canyon of the Deschutes River have yielded a fossil record of the upper John Day. In the higher

stratigraphic levels of this occurrence mammalian remains occur which on the basis of stage of evolution clearly represent a later level within the period of John Day deposition than any stage found in the type section. Our knowledge of the history of life for a particular depositional unit has thus been extended both in space and in time. Furthermore, the spatial extent of individual Tertiary faunas recognized in the John Day Valley is now established, especially with reference to the Mascall. Faunas of essentially the same composition as the Mascall of the type section have been uncovered near Roosevelt on the Columbia River, at Gateway north of Madras, Oregon, and in south central Oregon in and about Beatty Butte. At some of these localities certain kinds of Miocene mammals are represented by better material than at the type locality of the Mascall."

"Study of the northward extension of faunas in the typical John Day section into the region of Ellensburg in eastern Washington has demonstrated again the value of cooperative enterprise in such investigations. It emphasizes the service rendered by paleontology in the correct interpretation of a sequence of geologic episodes in south-central and eastern Washington. With a broadening of the field of investigation of the Ellensburg formation to encompass a larger geographic area, it can now be stated that more than one vertebrate faunal zone is present in the sequence of later Tertiary rocks of this region. With the active cooperation of Professor George F. Beck, of the Central Washington College of Education, fossil mammalian remains have been uncovered at a number of localities in eastern Washington. Study of these materials appears to show the presence of (1) mammals of Middle-Upper Miocene age and related Mascall types, (2) the *Hipparrison condoni* fauna of Mio-Pliocene age, and (3) a fauna with more advanced Hipparions and

approximately the correlation of the Rattle-snake Middle Pliocene.

"Much additional field work needs to be done in the area to define these faunal units clearly. Further investigation will unquestionably elucidate the faunal relations of the Ringold to the Taunton, and of the latter to the Upper Pliocene Hagerman fauna of Idaho. The fact that these studies relate to faunas represented in the type section of the John Day Valley of Oregon shows again how the horizon of geologic history moves outward or expands with progressive field investigation."

"In extension of other investigations correlated with those in the John Day area, during the past year special studies have been conducted in Tertiary formations exposed along the course of the San Andreas Rift in Cajon Pass, and on the western border of the Mohave Desert. Field work in this region was undertaken at the suggestion of Dr. Levi Noble, of the U. S. Geological Survey, who for many years has carried forward important structural geological studies along this part of the Rift. One noteworthy paleontological discovery has been recently made: a fairly complete skull of *Archaeohippus* was collected in the Cajon formation in Cajon Pass. This specimen furnishes additional evidence for an Upper Miocene age of the Cajon deposits. It likewise permits fairly complete knowledge of the skull and dentition of an important mid-Tertiary side branch in the evolution of the horse group. The specimen will be described in a paper to be submitted to the Institution for publication."

During the past year the following papers have been published:

DEMAY, I. S. Quaternary bird life of the McKittrick asphalt, California. Carnegie Inst. Wash. Pub. 530, Contr. to Paleontol., paper III, pp. 35-60 (1941).

— Pleistocene bird life of the Carpinteria asphalt, California. Carnegie Inst. Wash.

- Pub. 530, Contr. to Paleontol., paper IV, pp. 61-76 (1941).
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- FURLONG, E. L. A new pliocene antelope from Mexico, with remarks on some known antilocaprids. Carnegie Inst. Wash. Pub. 530, Contr. to Paleontol., paper II, pp. 25-33 (1941).
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Papers now in press: P. C. Henshaw, "A Tertiary mammalian fauna from the San Antonio Mountains near Tonapah, Nevada"; R. W. Wilson, "Preliminary study of the fauna of Rampart Cave, Arizona"; H. Howard, "A review of the American fossil storks."

Studies of E. L. Packard on marine invertebrate life of the John Day section. Through the work of Dr. E. L. Packard, of the State College of Oregon, with several assistants and associates, a very significant contribution has been made to the history of life in the John Day region by discovery of extensive series of the lower orders of animals in marine deposits forming a considerable part of the whole series of formations. Collections of these marine forms have been made at many localities in various parts of the area, including especially five localities in Wheeler County. These series of remains have been studied intensively, as regards both their position in the biological scale and their relation to faunas of other formations. These comparisons make it possible to determine the position of the formations in which the fossils occur in the time scale as worked out for other regions of America and Europe.

Detailed lists of faunas from Cretaceous deposits of the John Day region have been furnished by Dr. Packard in a manuscript which is prepared for early publication.

In this paper Dr. Packard has also given the data bearing on correlation with formations of other regions, especially the Upper Cretaceous of California. The contribution made by Dr. Packard is one of the most important studies of invertebrates of Cretaceous age in northwestern United States. Its value in geological, paleontological, and economic work will be demonstrated by future use of the data.

Progress in paleobotanical investigations in the John Day Basin, by R. W. Chaney. Approaching the subject of the history of plants with the training and the interests of both the botanist and the geologist, Dr. Chaney has spent the greater part of the past twenty-five years on the investigation of history of plants in the John Day area and in other regions the story of which is related to that of eastern Oregon. The result is a contribution of exceptional interest and importance both from the point of view of botany and geology, and from the point of view of the general student of evolution.

The following statement is an extract from Dr. Chaney's recent report on his researches:

"During the past twenty-five years, my studies have emphasized the record of plants in Tertiary deposits of western North America and northeastern Asia. Although there have been less marked changes in species-forming among angiosperms and conifers during the Cenozoic than has been the case with mammals, it has been possible to recognize a well defined sequence in Tertiary floral development. This has been based on the response of forests to climatic change, the altered distribution of vegetation resulting from progressive reductions of temperature and rainfall. As a result of this climatic trend, the vegetation in middle latitudes of western America has been altered from subtropical in the Eocene to moist temperate

in the Miocene, and to the present climatic regime involving summer drought and low winter temperatures. Judging from the plant record in northeastern Asia and other parts of the Northern Hemisphere, similar changes in climate appear to have been of wide extent during the Tertiary period.

"In order properly to establish and interpret these developmental trends in vegetation, it has been necessary (1) to follow the changes in forests throughout the Tertiary in a region where the record is essentially complete; and (2) to observe the simultaneous zoning of vegetation through many degrees of latitude during certain selected epochs. The latter has involved a comparison of Eocene vegetation from Alaska to southern California, and of Miocene vegetation from Washington to Mexico. In all cases where Tertiary forests have been so studied, there has been apparent a marked latitudinal differentiation, a zoning always well marked though often not so conspicuous as that of today. Studies of distribution during successive epochs of the Tertiary indicate a gradual southward migration of the holarctic element characterized by the redwood (*Sequoia*) and by many of the broad-leaved deciduous genera (*Acer*, *Alnus*, *Castanea*, *Carpinus*, *Fagus*, *Tilia*, *Ulmus*). Other important migrations have also been noted, but this southward movement seems to represent the most important single trend in Tertiary forest distribution, and to reflect the most widespread modification in climate during later geologic time.

"Changes in vegetation in a given region during the Tertiary are not always readily observable, since the record is rarely complete. Eastern Oregon, and specifically the John Day Basin, presents the most continuous sequence of terrestrial Tertiary deposits in western North America, and by far the most extensive sequence of Tertiary

floras on the continent. The record of Tertiary mammals is also exceptionally illuminating, and is closely associated with fossil plants. The Clarno flora, of Upper Eocene age, is made up of species whose modern equivalents are largely confined to the warmer parts of the world. The Bridge Creek flora, of Upper Oligocene age, represents the redwood forest now living on the Pacific coast, where the climate is moist and equable; it also includes important elements found in regions of summer rainfall in the eastern parts of North America and Asia. The Mascall flora is of Upper Miocene age, and shows lessened rainfall but continued temperate climate. Pliocene floras on the borders of the John Day Basin indicate an approach to the cool, semiarid conditions of today. This change in vegetation is interpreted as resulting from the uplift of the Cascade Range, with restriction of marine-controlled climate to its windward slopes. Similar floristic and climatic changes in other parts of the Northern Hemisphere suggest that factors more widely operative may also have been involved, such as variations in the solar constant or in the physicochemical properties of the atmosphere.

"With well characterized floral units showing this stratigraphic sequence and climatic trend, it has been possible to correlate floras in other parts of Oregon, and in Washington, Idaho, Nevada, and California. Present studies are emphasizing such correlations, and are involving a review of the John Day floras and their comparison with all related floras in western America. Checking the age of volcanic shales by means of their plant fossils, it has been possible to trace the equivalents of the Mascall formation into south-central Oregon (Stinking Water Basin), eastern Washington (Latah), western Idaho (Latah and Succor Creek), and southwestern Oregon (Ashland).

"It has further been possible to designate as of younger age certain deposits formerly considered to represent the time equivalents of the Mascall formation. Both the Dalles formation of north-central Oregon and the Ellensburg formation of eastern Washington have often been assigned to essentially the same age as the Mascall. Like this Middle Miocene formation of the John Day Basin, they are made up of light-colored volcanic sediments which occur in the section at or near the top of the Columbia River basalt. But unlike the vegetation of the Mascall, the Dalles and Ellensburg floras are characterized by semiarid rather than humid plants; the position of these floras in the climatic sequence, as established for the John Day Basin and other adjoining areas, is definitely near the close of the Tertiary, and they are referred without hesitation to the Pliocene.

"Continued studies will involve extensions of Bridge Creek and Clarno relationships into regions adjoining the John Day Basin. Already the study of the Florissant flora of Colorado has shown marked relationships with the Bridge Creek; this flora has been variously assigned to horizons from Eocene to Upper Miocene. Floras related to the Clarno are known to be of wide distribution in western North America. Clearly the John Day Basin becomes something more than a region in which geologic history is exceptionally well delineated, the life record more than usually complete. It serves as a point of reference from which the history of the surrounding areas may be worked out. Such correlations are possible not only in the Columbia Plateau and northern Great Basin; studies already under way in the coastal parts of Washington, Oregon, and California, with their records of shore deposition and marine fossils, indicate definite floral relationships. Through the use

of fossil floras over this wide area, and the faunas of land and sea, the later earth history of western America may come to be better understood."

Human interpretation of historical record in the John Day region. However important the technical record of any scientific research may be, ultimately its results must be translated and made clear to intelligent persons in all fields of activity. So it is desirable that there be such accounts of the John Day story as can be read easily by engineers, agriculturists, and students of natural resources. Articles of this nature have already been published, but it is hoped that still other literature may be prepared that will cover the whole story, including discussion of interrelation among the various types of researches so well expressed in this region.

The State Park organization of Oregon has already taken steps to make the striking natural features available to interested observers. Through the interest of Mr. Samuel H. Boardman, head of the Oregon State Parks organization, there have been secured in the John Day region a considerable number of spectacular areas which are now under control of the government as state parks. From the main highway which traverses this region it is easy to visit these features. It has been proposed that a small, generally intelligible book be prepared to describe and interpret the state parks of the John Day region. A further plan suggests that a considerable reservation be obtained, including the state parks and other areas of special importance extending along the John Day River in a region where practically the whole section of formations is well exposed. Such an area would not necessarily be defined as a park, but might become recognized as a region maintained in the interest of the public, by cooperation of the owners of the land. A new organization, sponsored by

the Board of Higher Education of Oregon and known as the Advisory Board on Educational Problems of Oregon Parks, is expected to have great influence in guiding the policy of the state toward utilization of great human values in natural features of the state.

RESEARCH ON THE RANCHO LA BREA FAUNA

Research on the Rancho La Brea project has become sharply divided into two parts: first, those studies which relate to specific kinds of organisms found in the Pleistocene asphalt deposits of Rancho La Brea and in related occurrences, and, second, studies which have to do with the development of Hancock Park, where the famous deposits are found, as an exhibit of exceptional scientific and popular interest.

Under the first subproject may be listed the studies which relate to the hoofed animals from the tar beds. Comprehensive treatment of these groups is given because these forms from the Ice Age are much better preserved and are far more abundant in the tar than elsewhere. These monographic studies thus serve as a basis for all further work on the Pleistocene faunas of the New World, where opportunities for comparison are limited because of the fragmentary state of the paleontological record.

Because of the abundance of fossil bird remains at Rancho La Brea, it is now possible to obtain mounted specimens of many of the characteristic types of Pleistocene birds found in the asphalt. Skeletal and skull elements of several distinctive kinds of birds have been selected by Dr. Hildegarde Howard. Eugene Fischer, preparator at the Los Angeles Museum, has completed the mounting of three species of birds, namely, (1) the stork *Ciconia maltha*, (2) the extinct turkey *Parapavo californicus*, and (3) the caracara *Polyborus prelutosus*. A paper by Dr. Howard

on the extinct storks from the asphalt has been submitted to the Carnegie Institution of Washington for publication (see p. 320).

Miss Ida S. DeMay recently published in the Carnegie Institution of Washington "Contributions to Paleontology" two important papers relating to the Quaternary birds from the Carpinteria and McKittrick asphalt deposits (see pp. 319-320).

The original guidebook on Rancho La Brea published by the Los Angeles Museum has now been completely revised and the text and illustrations have been submitted for a new edition.

Considerable progress has been made with the second subproject, that which relates to the development of Hancock Park. The Los Angeles County Planning Commission has approved a basic plan for improvement of the 23 acres which comprise the park. This involves some grading of the area, the laying out of roads and paths, and ultimately the planting of a flora similar in composition to that which grew in the region during the time of entombment of the sabre-tooth, the dire wolf, the ground sloth, and the many other kinds of animals which frequented Rancho La Brea during the Ice Age.

Plans are in progress by the architect for a structure adjacent to one of the fossiliferous asphalt deposits in Hancock Park. This building will furnish opportunity for visitors to see actual bones and skulls of prehistoric creatures in place in the tar. The exhibit will be so arranged that the observer can not only view the fossil remains as they are exposed near the top of a typical excavation, but likewise see them in a cross section of the brea. The building will contain also one large room in which supplemental exhibits are planned. These will relate to the geologic history of Los Angeles Basin, the relation of the older rock formations to Rancho La

Brea, and the formation of brea accumulations such as those found at this locality.

EVOLUTION OF GROUPS OF ANIMALS ESPECIALLY USEFUL IN STUDY OF THE PROBLEM OF EVOLUTION

Several groups of animals of which relatively abundant fossil remains have been found and which seem to offer opportunity for studies of evolution have been examined with particular care in part by the writer, and in part by students and associated investigators. These types of life include the ancient marine reptiles known as ichthyosaurs; a corresponding marine group in the division of the Mammalia, or the highest animals, is recognized in the whales. Evolution of the whale group became the special subject of investigation for Dr. Remington Kellogg, Curator of Mammals at the U. S. National Museum. Mr. E. L. Furlong, of the University of California and later of California Institute of Technology, has given special attention to the study of the evolution of the antelopes, of which many fossil remains are known from the region of eastern Oregon and northern Nevada.

The ichthyosaurs have been especially interesting from the point of view of evolution, as we know their story of development through a very long period, in which they became highly specialized in the direction of adaptation to life in the ocean. The changes in direction of specialization went forward very rapidly in some cases, and seem to show certain aspects of the ways in which evolution may take place. The writer became acquainted with the importance of this group in the middle nineties, and a long series of papers on the general subject of the evolution of ichthyosaurs was published, culminating in a monograph on *Triassic Ichthyosauria*, published in 1908. A number of further small papers on various aspects of the evo-

lution of the ichthyosaurs have been far advanced toward completion, and it is hoped that these pieces of work may be finished for publication, and that others may carry forward study of the ichthyosaurs to significant results.

Studies on the history, adaptation, and evolution of whales, by Remington Kellogg. These investigations have continued to make extremely interesting contribution to knowledge of development in the higher animals. The high degree of variability and specialization in the whales, considered with their wide geographical distribution and long geological range, have made this group of animals one of the most important objects for study on the broader field of evolution and its meaning.

Dr. Kellogg has concentrated effort recently on investigation of the geologic history and relationships of the cetotheres, the predecessors of the Recent whalebone whales. Critical comparison has indicated that some of the types of cranial construction have developed in several ways. Whether or not any of these lines proved successful for any length of time cannot yet be demonstrated from the material available in collections.

Particular attention is now being given to the cranial changes that make their appearance in the cetotheres belonging to three successive Miocene faunas of the east coast, the Calvert, the Choptank, and the St. Marys. The evidence at hand suggests that the geologic span of these Miocene cetotheres was of short duration, since none of the Calvert forms have been recognized in the St. Marys formation.

Some of the more generalized types of cranial architecture exhibited in Miocene cetotheres are duplicated in part in certain stages of the fetal development of Recent mysticete skulls. A series of these fetal skulls is being studied in conjunction with the fossil material. As yet, it has not been

possible to obtain fetal skulls of the gray whale, *Rhachianectes glaucus*.

During August 1940 and July 1941, the Miocene cliffs on the western shore of Chesapeake Bay from Plum Point to Flag Pond were searched for additional cetotheres remains.

The following publication has appeared:

On the cetotheres figured by Vandelli. Boletim Museu de Mineralogia e Geologia da Universidade de Lisboa, nos. 7-8, pp. 13-22 (1941).

Evolution of American antelopes, by E. L. Furlong. A group of researches of particular interest is that conducted by Mr. E. L. Furlong, designed to interpret the history or evolution of the antelope group in America. These studies were initiated many years ago through examination of materials obtained in eastern Oregon, northwestern Nevada, and middle California. Mr. Furlong's long-continued and painstaking studies give us a rich series of antelope types, in which both the degree of specialization and the evidence of effectiveness in activity of the organism illustrate the importance of the idea of modification, development, and progress of organic types.

The results of Mr. Furlong's work on the Antilocapridae, or antelope group, during the past year record a definite advance in study of several of the types concerning which additional information has been desirable. Among these are the generic groups *Tetrameryx* and *Hexobelomeryx*, with allied forms. Among the details of this study, Mr. Furlong has worked out methods through which it is possible to determine the age of individuals by measurements of isolated bones and teeth.

Probably the most important contribution of Mr. Furlong's studies on the antelopes relates to evolutionary changes leading to various kinds of specialization. One of the most puzzling of the several ante-

lope forms obtained shows close resemblance in the bony horn cores to horns of the well known kudu or twisted-horned antelope of Africa. This resemblance is so strong that some investigators were inclined immediately to accept the idea that American specimens belonged to the same group as the kudus of Africa, but later investigations have shown quite conclusively that the American kudu-like type is a different animal with a distinct type of structure, especially in the dentition, and that similarity in the horns is due to evolution along lines parallel to those followed by the African animal.

The stages of development of the American antelopes illustrate quite clearly how the modern pronghorn developed out of an earlier type. Curiously enough, the pronged horn of the present-day animal shows in the horny sheath covering the long bony core a structure which was expressed in the horn core of the earlier antilocaprids.

These studies have shown that numerous offshoots of *Merycodus* have developed since early Miocene time. Also there was a notable increase in species of the Antilocapridae in the Middle Pliocene and Pleistocene, and an equally rapid extinction of forms, leaving only the pronghorn to represent the group today.

Mr. Furlong has also shown that, whereas antelope remains were for a long time almost unknown in most of the later formations of western North America, they are now seen to be sufficiently abundant to make possible their use in determining the age of formations, and also in the mapping of formations for either scientific or economic purposes.

STUDIES ON THE HISTORY OF EARLY MAN

The story of beginnings in human history has shown itself to be so closely interlocked with many aspects of paleontol-

ogy and geology that it appears important to carry these subjects along together if we are to secure the most trustworthy results. In America the account of man's appearance and of his development is closely tied in with history of the late glacial stages and with much that concerns evolution of existing land features. Also, as there is evidence of definite changes in the life of the higher orders of mammals in America during the early part of man's presence on this continent, one naturally inquires whether human evolution has gone forward at a rate corresponding to that of other creatures.

Researches in this subject have continued through the past year over a wide field reaching from the region of earliest known human remains in Java to various sites in the United States. In all these studies the writer has been grateful for continuing counsel and advice from Dr. E. B. Howard, of the University of Pennsylvania, one of the leaders in correlated studies of early man in America.

Researches of G. H. R. von Koenigswald. The work of Dr. von Koenigswald done in cooperation with the Carnegie Institution in recent years on the problem of early man in Java constitutes one of the most significant contributions of recent decades. A part of a report by Dr. von Koenigswald is presented, as follows:

"During recent years more remains of *Pithecanthropus* have been discovered by the present author with the assistance of the Carnegie Institution of Washington, and now comparison with the man-apes of South Africa has become possible. The new material demonstrates beyond any doubt that *Pithecanthropus* is a member of the human family. Among the new materials there is the heavy mandible B, which can be directly compared with the heavy mandible of *Paranthropus*. Then we have the skull-cap *Pithecanthropus* II

of a female individual, and the incomplete male skull IV shows the upper palate. This last skull has not been described.

"The heavy lower jaw of *Pithecanthropus* B, fitting perfectly into the upper jaw of the big skull IV, certainly belongs to a male individual, and the same is to be said of the heavy mandible of *Paranthropus*. In *Pithecanthropus* only the second premolar and the three molars have been preserved. The teeth are worn and not in the best condition, but show sufficient details. All teeth are very large, larger than in recent man, but smaller than in *Paranthropus* and the other *Australopithecinae*.

"In *Pithecanthropus* can be observed a very remarkable and decided increase in length from the first to the third molar. These conditions are very unexpected in a hominid, as in recent man the first molar is usually the largest and the third irregular and often missing. Already in *Sinanthropus*, although in the heavy mandible G the second molar is larger than the first, the average of both of these molars *in situ* shows exactly the same value (12.6 mm.), and the third molar is reduced. In recent man the average for the first molar is 11.1 mm. and for the second 10.7 mm., according to De Jonge-Cohen.

"The largest brain capacity observed among the living anthropoids is about 650 cc. for a male gorilla. In *Pithecanthropus*, our most primitive ancestor, we have evidence that the capacity is only 800-1000 cc.; in *Sinanthropus*, the Peking man, 900-1200 cc. In Neanderthal man the capacity is already about 1250-1400 cc. (for the big skull of La Chapelle even 1620 cc.), and in recent man of the white race 1350 cc. (female, average) and 1500 (male, average). There are also signs of an increase in bodily size. Weidenreich estimates the size of a female *Sinanthropus* at 152 cm. only, Boule that of Neanderthal man at 155-160 cm. At the same time,

however, a reduction of the jaws and of the dentition is observed. Neanderthal man has larger teeth than recent man, but the teeth of Peking man are still larger, and the largest teeth are found in *Pithecanthropus*.

"We have to assume in man's earliest forerunners a moderate increase in size both of the prehuman dentition and of the prehuman brain, in about the same degree as we find it in the living anthropoids. After the invention of implements, however, he no longer needed his teeth to tear his food to pieces, nor big jaw muscles which pressed his brain case. The skull of a young anthropoid is rounded and much more human-like than an adult one, which changes its form under the pressure of enormous jaw muscles. Even in *Pithecanthropus* we observe that the juvenile skull from the Lower Pleistocene of Modjokerte (*Homo modjokerensis*) has a more human appearance than the adult ones. Soon man discovered the use of fire and began to cook his food. He used his teeth in a way different from his anthropomorphic ancestors. When he began to talk he also used his jaw muscles in a different way. Only in the development of civilization can we find a reason for the typically human evolution: the reduction of the dentition combined with an astonishing, progressive development of the brain—both surely interdependent—which makes man a human being."

Investigations in early human history, by L. S. Cressman. The work of Dr. Cressman during the past year has tied together much of the wide range of subjects assembled in recent years of field work and laboratory study. The advance in our knowledge of this section of history made by the work of Dr. Cressman is extremely important, and gives to the region of Oregon with which he has been con-

cerned greatly increased value in the attempt to piece out the story of man on this continent. In the following extract from Dr. Cressman's report, references to work of Williams and Antevs will be fully explained by reference to Dr. Cressman's report printed with Dr. Merriam's report in Year Book No. 39 (1939-1940), pages 300-306.

"In the field the real contribution to the study of early man and the prehistory of the Northern Basin has resulted from the cooperation of specialists from different fields. The geological contributions of Williams and Antevs in the earlier part of the work gave a geological frame of reference within which the anthropological results gained significance. Williams' work gave a time significance to our anthropological material which required a new formulation of the theory of cultural relationships between the Northern Basin and the Southwest, with especial reference to the Basket Makers of the San Juan. According to these results, affiliations of the Basket Maker culture may now be considered as being later instead of earlier, which forces a reconsideration of the theory that the Northern Basin culture as illustrated from the Oregon caves is derived from post-Basket Maker horizons.

"Studies of the artifacts from related horizons show that the Oregon materials are basically a part of the widely diffused simple pre-agricultural horizon extending into northern Mexico, east across Texas, and into the Ozarks. Oregon, like each of the other main areas, as time went on developed certain regional complexes partly dependent on the different offerings of the environment and partly on certain directions the culture was given because of local peculiarities and their impact on the minds working with them. It should be emphasized that the formulation of

these problems has grown out of the results of the combined work of the archaeologist and the geologist.

"The work in the Tule Lake region has been another example of a problem which has been fairly successfully approached by cooperative attack. Here for the first time in the Northwest archaeologist, botanist, geologist, paleontologist, conchologist, and others have cooperated on a problem and found significant results. The work of Antevs, Allison, and Smith on the geological aspects of the problem with special reference to the time of the extinct beach formulated certain theories that the beach represented the Little Pluvial period. This was but one hypothesis, but on the basis of geological evidence it was the most likely. Examination of the pollen profile by Dr. Hansen, of Oregon State College, has tended to confirm this theory of the age of the extinct beach and the cultural horizon in the peat formed at the beginning of the Little Pluvial. Mr. Conger could find no evidence of climatic change in the diatoms from samples taken from the same material from which the pollen profile was constructed. This was to be expected since the lake evidently was never very alkaline, having been built up from the backwater of the overflow of the outlet of Upper Klamath Lake. Mr. Conger feels that the great number of diatoms at certain levels gives evidence of volcanism, and this agrees with Hansen's report so far as can be judged from correspondence. A series of pollen profiles has been constructed and should be useful for studies of climatic variation in future problems.

"Dr. Frank Baker, of the University of Illinois, examined the molluscan material and says: 'They are of extreme interest from a distributional viewpoint. The fauna contains an assemblage of species and races quite different from the recent fauna now living in Upper Klamath Lake

and also different from the fauna living in Lower Klamath Lake before it was drained. . . . The most abundant species represented are the two *Valvatas*, *platyceps* and *densestriata*, which have previously been known only from the Pliocene deposits in the Kettleman Hills oil region in Kings County, California. Neither race has previously been reported from any later deposit or from the recent fauna. . . . The new *Gyraulus cressmani* is almost as abundant in individuals as the *Valvatas*. . . . Apparently the same form occurs in fossil deposits near Indio, California.'

"A hasty examination of the vertebrate remains by Mr. Furlong showed that there were horse, camel, deer, elk (?), peccary (?), and Carnivora in the assemblage sent for examination. A full report will clear up the doubtful types. Elephant of some species was also found, but no teeth and probably insufficient skeletal material for more detailed identification. This fossil fauna comes from the earliest horizon in Lower Klamath Lake.

"The cultural material shows different horizons and finally a culture that was possibly the antecedent type from which the historic culture of the Klamath Lake region developed.

"Examination of collections in the Carnegie Institution's possession at Boulder, Colorado, excavated by Dr. Earl Morris, turned up a number of specimens which had not been reported and which in the writer's opinion show the northern affiliation of the Basket Maker culture represented by them. The same is true of materials from Basket Maker sites represented in the American Museum of Natural History."

Studies of Chester Stock on prehistoric archaeology. Publication in the Fiftieth Anniversary Volume of the Geological Society of America of a chapter on "Prehistoric archeology" by Dr. Chester Stock

calls especial attention to the work done by him in maintaining the close relation between paleontology and archaeology that is essential to clear understanding of early stages in human history (see p. 320).

Geological contributions of Howel Williams bearing on the studies of early man. The researches of Dr. Howel Williams on history of the Crater Lake region of Oregon have contributed most valuable data in connection with the studies of Dr. Cressman on early man in that region. Williams' investigation of the origin of ash deposits in the region around Crater Lake has shown that ashes erupted from Mount Mazama, the volcano from which the crater of Crater Lake was derived, were deposited in the surrounding area after human beings had come to occupy the region.

The Williams study of the Crater Lake area furnishes an extremely valuable connection between the geological record and the story of early man.

Investigation of the sedimentary sequence of deposits at Fossil Lake, Oregon, and of conditions under which the formations were laid down, by Ira S. Allison. Fossil Lake is a classic locality for the occurrence of fossil mammals with the possibility of intermingling of human remains with the bones of extinct creatures. Though much has been written on the subject, the conditions of origin and deposition of the Fossil Lake deposits have constituted a problem not fully understood for many years. The work of Dr. Ira S. Allison, of the State College of Oregon, during the past two years has made important contribution both to understanding of the relation of this formation to problems concerning early man, and with regard to types of conditions which obtained in south-central Oregon during the latter part of Pleistocene time and the beginning of the present period.

The following statement is quoted from a report of Dr. Allison written at the end of the 1941 field season:

"Special attention was given to the uppermost beds, with which the major fossils are associated. On the basis of these field studies and of petrographic studies made in the laboratories of Oregon State College, principally by Hollis Dole, a graduate student, certain generalizations can now be made.

"The sediments of the Fort Rock-Silver Lake-Christmas Lake-Fossil Lake basin may be divided into two groups: (a) the lower, uniform, even-bedded, massive-appearing but actually laminated beds of silty volcanic ash and diatomite in varying proportions, and (b) the upper, variable beds of sand, silt, pumice, gravel, and even boulders, capped by a widespread lake-laid sheet of pumice. At the contact between the two phases is a breccia or conglomerate composed in part of fragments of the underlying lake beds; other re-worked sediments also appear in the upper beds.

"The lower beds are clearly the product of a deep lake supporting abundant growth of diatoms and receiving occasional falls of volcanic ash. This is in line with two prominent shore lines, which stand about 210 and 160 feet respectively above the present floor of the basin. The upper beds, on the other hand, with their coarser grain sizes, cross-bedding, ripple marks, and disturbed bedding, are the product of a shallow lake whose shore line was not more than 20 to 30 feet above the lake floor. It should be noted that this latter lake, though shallow, covered most of the bottom of the basin. The older beds attain thicknesses of at least 50 feet, but the base is not exposed, whereas the upper beds generally range from about 3 to 15 feet in total thickness.

"The principal mammal fossil horizon

at Fossil Lake is at or near the base of the upper group of beds, and bird bones are most common in certain sands a few feet higher. Fossil fish bones, however, have been found throughout the older beds, in the sands and breccias, and in the uppermost or final layer of volcanic ash of the upper series.

"The presence of mammals out on the floor of the basin several miles from the former shores indicates that the large, deep lake had virtually disappeared when such animals had access to the area. The restriction of the mammal fossils to one part of the basin suggests that this area was the site of a water hole or marsh. Subsequent return of lacustrine conditions served to bury and preserve their remains.

"Certain sedimentary features (though salts to be expected from desiccation are not known) and the high percentage (65 per cent) of extinct species of mammals included in the fauna suggest that there may have been a considerable lapse of time between the decline of the large, deep lake and the reappearance of the lake represented by the upper series of beds. During that time a great flood of lava entered the northwestern part of the basin from Lava Craters on the south slopes of Newberry Crater, and spread almost to Fort Rock. This lava field is thought to conceal the former outlet of the deep lake over the rim of the Deschutes River basin southwest of Newberry Crater. The later, low-level lake was still in existence when Newberry Crater (or some subsidiary vent) gave forth its final output of pumice, part of which was distributed widely in the lake. Pumice of pebble sizes on the west and northwest was thrown up on beaches, spits, and other shore forms, especially on the eastern and northern sides of bays, whereas particles of finer size farther east accumulated in part on shore but more largely as silt on the bottom of

the lake. Only the low-level beach gravels include pumice pebbles, thus limiting the maximum depth of the lake at the stage of this last pumice eruption.

"The subsequent history of the area includes: (1) extinction of the low-level lake which received the Newberry pumice fall, (2) an extreme drying of the climate and consequent excavation by the wind of blowouts ranging in depth from a few feet to several tens of feet and in area from small patches to broad basins covering many acres, (3) redistribution of the pumice and excavated material by the wind, (4) a return of more humid conditions so that certain of these wind-made basins became sites of ponds or lakes, some of which, for example Thorn Lake and Fossil Lake, persisted to modern time, and (5) disappearance of Fossil Lake, Thorn Lake, Silver Lake, etc., and renewed vigor of wind work both in deflation and in dune movement. The exposure of the fossils at Fossil Lake is one of the effects of wind erosion.

"The great depth of the early lake and the limited depth of the later one call to mind the similar sequence of strong Tahoe and weak Tioga glacial stages of the Sierra Nevada and suggest their direct correlation therewith, inasmuch as glacial stages and interior lakes must both have been dependent on common climatic factors. The mammal fauna of Fossil Lake then would be post-Tahoe but pre-Tioga in age and hence perhaps 100,000 years old instead of 20,000 or less."

RECENT RESEARCH ON MAJOR PROBLEMS OF THE GRAND CANYON AREA

During the past year Mr. Edwin McKee has continued his studies on problems of the Grand Canyon area begun during the period of his service as Chief Naturalist at the Grand Canyon. These investigations

have produced important paleontological and geological results. The following is quoted from a report by Mr. McKee on some of these studies:

"During the past season a detailed investigation of the Cambrian strata of Grand Canyon, carried on over a period of six years, has been nearly completed, and work on the manuscript of a paper describing this study has made good progress. A previously unvisited and critical section of the Cambrian at Grand Wash Cliffs was examined, and sections at Toroweap, Diamond Creek, and Meriwitica Canyon were re-examined in order to check certain details in the light of recently developed theories. A geological traverse from eastern Grand Canyon to the Desert Range of Nevada was made during March in company with Professor Longwell, of Yale University, and Mr. John Shelton, of Pomona College, for the purpose of demonstrating the validity of correlations and checking the nature of lateral transitions among the Cambrian rocks. This traverse also made possible a comparison of strata in adjoining areas, these being studied by the several geologists in the party."

"Other recent work has included a detailed study of a nearly landlocked Cambrian bay, the traces of which may be seen clearly in the walls of Grand Canyon below Yavapai Point. The environment, as represented by its sediments, forms an interesting contrast with that of adjoining areas which were in the open sea.

"Two principles of stratigraphy of major importance have been demonstrated by the evidence gathered on this study of Cambrian formations. The proof has been made possible by the excellence of exposures and the great distances over which they can actually be traced. One of the principles is that the faunas are distributed according to certain environmental facies and not, as was formerly supposed, accord-

ing to a simple time sequence. Certain types of fossils and certain types of lithology are shown to recur at several different times but in widely separated areas, owing to the recurrence of certain environmental factors across the path of a transgressing sea. The second principle is that 'time lines,' represented by continuous fossil zones, do not parallel the formation or lithologic lines, but cut diagonally across them in an east-west direction or at right angles to the geosyncline. Thus, the top of the Tapeats sandstone is shown to be much older at the western end of Grand Canyon than at the eastern.

"Other studies now nearing completion are of the principal lithologic types, especially as regards their significance in terms of environment. These may conveniently be classed as facies, of which there are seven major ones: the coarse near-shore sands, the green shales, the fine offshore sands, the iron-glaucite rocks, the 'snuff' dolomites, the 'girvanella' limestones, and the aphanitic, mottled limestones. These various types are interrelated and show a natural sequence from the east or shore side toward the west or geosyncline—a sequence which is repeated many times in the Cambrian section and whose position at any particular time shows the stage of advance or retreat of the sea.

"Examination of the Cambrian faunas has been made by Dr. C. E. Resser, of the U. S. National Museum, and descriptions of the new species have been completed by him. It is planned that these will be included in the monograph on the Cambrian of Grand Canyon."

STUDY OF CAVE PROBLEMS

Mr. E. L. Furlong has been active in the past year in carrying forward study of life in the later formations of California through examination of materials in those

especially well protected reservoirs of remains of the past, limestone caves. A report by Mr. H. W. Buckingham, of Redding, California, on the finding of interesting caves in the McCloud River region led to the cooperation of Mr. Furlong and Mr. Buckingham in study of a new locality for fossil remains of Pleistocene age in the "Stone Man Cave" near Baird on the McCloud River. The remains obtained at this locality show certain resemblance to materials obtained from Samwel Cave and Potter Creek Cave in the same region. There are, however, slight differences, and although the age of all these deposits falls within a limited division of Pleistocene time, it is probable that they represent different time stages.

FURLONG, E. L. Stone Man Cave, Shasta County, California. *Science*, vol. 94, pp. 414-415 (1941).

CORRELATION PAPER ON TERTIARY FORMATIONS OF THE GREAT BASIN REGION

An elaborate paper prepared during several years in collaboration with J. P. Buwalda and Chester Stock covers correlation of the formations of the Great Basin region, with particular reference to their time sequence. Since it appears that results of some of our recent researches, as also those of other investigators, have shifted the time levels of certain of the formations, it becomes essential to review the whole subject with care before the paper is published. This work of review is now under way.

CONTRIBUTION OF PALEONTOLOGICAL AND GEOLOGICAL SCIENCE TO HUMAN PHILOSOPHY OF THE PRESENT AND FUTURE

In the reports on studies undertaken during the past two years, effort has been made to set down clearly certain general statements regarding philosophical con-

clusions from technical research, and also some discussion of human values which may be expected to grow out of such studies.

In the report of 1939 (Year Book No. 38), under the head of "Basic questions that have arisen from research," attention was called to several problems, some of which had to do with the philosophy of science itself. One of these arose from the work being done by Mr. McKee at the Grand Canyon on the relation between development of species in space, in a measure by adaptation to environment, and their development through time under influence of factors not yet fully understood. From Mr. McKee's report of the past year's work it appears that this relation is more complicated than has perhaps been assumed. Fortunately, the Grand Canyon gives almost ideal means for study of these questions.

Another question concerned the possibility of obtaining information as to the extent to which evolutionary changes in the history of early man run parallel to changes expressed in paleontological or geological history; that is, as to whether the influences which have determined in some measure the evolution of other organisms have also been effective in the development of man. Though no complete solution of this problem has yet been obtained, the work on early man done by those who have been cooperating with us, especially in the Oregon region, is bringing out gradually a sequence of geological and paleontological events which seem to run parallel to important events in the history of man.

The 1939 report also mentioned the fact that study had been given to the selection of regions of particular importance for bringing out philosophical or educational or scientific values in natural features, with expectation that contact with their reali-

ties would have much educational influence. This program has been continued, and a considerable group of new areas has been selected and studied for this purpose.

A considerable part of Dr. Merriam's effort in discussion and writing in recent years has been devoted to the question of the influence of science and the realities of nature upon human thought. No doubt, if it were possible to turn the course of thinking of humanity toward the great inspiring features in nature, it would not only be possible to prevent much of the disturbing thought which has caused the great fires which spread over the world, but it would be possible also to direct our thinking toward the highest types of healing value which can be brought to bear upon the human mind.

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MERRIAM, JOHN C. Present day influence of inspirational and healing values in nature.

LLEWELLYN IVOR PRICE, Museum of Comparative Zoölogy, Harvard University, Cambridge, Massachusetts. *Studies of vertebrate paleontology in Brazil*

Dr. Price has spent the past year in laboratory and field studies in Brazil. He has worked in the laboratories of the Divisão de Geologia e Mineralogia (Geological Survey) and in the Museu Nacional in Rio de Janeiro, has engaged in field expeditions in the states of Bahia and São Paulo, and has begun studies in a new fossil region in Matto Grosso. These activities have been supported by a grant from the Carnegie Corporation of New York administered through the Carnegie Institution of Washington.

Dr. Anibal Alves Bastos, Director of the Divisão de Geologia e Mineralogia, and Dra. Heloisa Alberto Torres, Director of the Museu Nacional, have graciously

Founders Day Address, Lafayette College, November 1, 1940.

— Responsibility of science in planning for a new world order. Address at dedication of Hancock Hall, Allan Hancock Foundation for Scientific Research, The University of Southern California, January 3, 1941. Printed in *Proceedings of Dedicatory Exercises* (1941).

— Origin and evolution of cultures in America—Common interests in nature expressed by peoples of America. In address before Third General Assembly, Pan American Institute of Geography and History, Lima, Peru, April 6, 1941. Proc. Pan American Inst. Geogr. and Hist. (1941).

— Cultural objectives as a basis for international understanding. Address before American Academy of Public Affairs, Los Angeles, California, May 27, 1941. Los Angeles Daily Jour., Aug. 20, 1941, p. 1; Aug. 21, 1941, p. 1.

— Charm of nature an asset of Oregon. (Extracts) Summer Sun (Eugene, Ore.), vol. 22, p. 3 (1941).

— The highest uses of the redwoods, being the messages of the President of the Save the Redwoods League to the council 1922-41. 47 pp. San Francisco, Save the Redwoods League (1941).

and fully cooperated with Dr. Price and have made all possible facilities available to him. The entire fossil collection of the Survey, vertebrates, invertebrates, and plants—about 200,000 specimens—is being reorganized and catalogued for the first time. In the Museum the entire collection, some 100,000 specimens, has been adequately housed, the vertebrate collection has been organized, and a catalogue initiated. Dr. Price has been able to help in improving library facilities, has delivered a series of technical and popular lectures on vertebrate paleontology, and has begun instruction of young assistants to aid him and to carry on his work. He has completed a preliminary paper, "Notes on an

articulated rhynchosaur skeleton," written in Portuguese for publication by the Survey. A second preliminary paper, "On *Mawsonia gigas*," is under way, and Dr. Price is accumulating material for a complete review of Brazilian vertebrate paleontology.

An expedition to the Cretaceous and Tertiary strata of northeastern Bahia lasted nearly three months. Large collections of fossils were made, which include a large fossil fish fauna, a smaller reptilian fauna, invertebrates, and plants. By far the best collection was taken in the Cretaceous of Ilha de Itaparica. Here over one hundred specimens of fishes were removed, including two apparently new forms. Two magnificent specimens of the lepidotid *Maw-*

sonia gigas were found. This material is of particular interest, for it will serve as a basis whereby many isolated Cretaceous areas in northern Brazil may be correlated.

Another month was spent traveling over the western half of the state of São Paulo in an attempt to select areas that merit careful search for fossils. Such areas were chosen in the Permian, Triassic, and Juro-Cretaceous strata, and a small collection of the reptile *Mesosaurus* was made during the investigation of the Permian section.

The studies that Dr. Price has started in Matto Grosso, and upon which a later report will be submitted, will fill a gap in the geological map and add a page to the history of dinosaurs.

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525. Contributions to Embryology, volume XXIX. Quarto, iii+193 pages, 57 plates, 27 text figures.
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180. LEWIS, WARREN H., and CARL G. HARTMAN. Tubal ova of the rhesus monkey. Pages 7-14, 1 plate.
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